# COLOR IN ARCHITECTURE

By

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A Thesis

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[signature]

Chairman of Committee

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ILLUSTRATIONS

# PART I

## O B J E C T I V E S

These are the objectives of this thesis:

1. To prove the importance of color in architecture.
2. To provide a reference summarizing briefly what is known about color.
3. To test my own color sense.
4. To arrive at conclusions on the approach to color in architectural training.

## 1 - The Importance of Color in Architecture

Good design can be spoiled by poor color. Weak design can be helped by good color. Color is therefore of prime importance as an integral element of architectural design.

Color is vitally related to man in many fields. The study of architecture involves the study of living - a thorough inspection of the behavior of man. Color in architecture, then, can be understood only by studying color in many fields.

## 2 - What Is Known about Color

Suppose you, as an architect, were asked these questions:

"What color should a factory be painted?"

"Will this color of brick look good on this house?"

"What sort of lighting should be put in a restaurant?"

"Do you like the colors of that building?" "Why?"

"How are colors exactly specified?"

"How do you explain the use of color in modern art?"

"What is color-blindness?"

To be able to answer such questions, you would need considerable knowledge of the fundamentals of color. Perhaps not every architect should be able to supply all the answers, but every architectural firm should possess this knowledge.

To begin with, something of the history of color should be known. Then should come a study of color through physics, through physiology, through psychology, through art, and through illuminating engineering. The scientific study of color began with Newton in 1666, but most of our knowledge of color was obtained much more recently. A study of color in various fields will involve, of course, repeated overlapping of those fields.

## 3 - My Own Color Sense

This research will prove somewhat futile if I do not have either a good color sense or the capacity to develop a good color sense. One way of testing my color sense is by checking my opinion against public opinion. Such a test is included here in Part III. A further check against professional opinion may prove something.

## 4 - Conclusions on the Approach to Color in Architectural Training

Any conclusions which I draw will necessarily be personal, depending on my own color sense. However, the "approach" to color is different from arbitrary assumptions about color. A proper approach to color will involve not only the application of what is already known, but also continual experimenting. Such an approach must educate both architectural students and their instructor.

# PART II

## W H A T I S K N O W N A B O U T C O L O R

# HISTORY

## Significance of Color through the Ages

In ancient days color was related to the supernatural rather than to the esthetic. The Egyptian sun god, Ra, was said to have risen from earth to sky, where he controlled lightness and darkness, thereby controlling the visibility of color. The hues of the rainbow were considered sacred and were made a part of hieroglyphics.

The "Golden Age" of Greece was full of color symbolism. Garments were a sign of achievement, notably the golden robe of Athena. Purple was worn to recite the sea travels of Ulysses, while red was worn to recite the Iliad.

The Orient promoted the sacredness of yellow, which was the color of Brahmanism, of Buddha, and of Confucius. Confucius hated purple because to him it confused with red, "just as goody-goodies confuse with virtuous people".

The Mohammedans favored green and gold, while Judaism and Christianity mentioned various colors.

Ancient buildings were given colors which related to planets, as the Temple of Nebuchadnezzar at Barsippa whose seven colors were related to seven planets, including the sun and the moon. One of the oldest buildings of history - about 2300 B.C., the "Mountain of God" between Bagdad and the Persian Gulf, was colored to signify the underworld, the earth, the heavens, and the sun. This may have been the home of Abraham.

Color is significant in astrology. There is a color for each sign of the Zodiac. In ancient Chinese astrology, the colors of the planets forecast the weather and the prospects for war.

Pride in skin color has characterized all races. Indeed, history shows that races were designated by color by the Egyptians, by the Assyrians, by the Arabs, by the Indians with their castes specified by color, and even by present-day reference.

Color has been related to healing since the days of Hermes Trismegistus of Egypt. Some ancient miracles were related to color rather than to chemistry. After Hippocrates, opinion on color as a healing force was divided between the mystics and the clinicians.

Avicenna the Arabian in the 10th and 11th centuries used color as a guide in diagnosis, also as a curative. Avicenna noted the significance of the color of hair, skin, eyes, excrement, and urine. He assigned hot temperaments to people with black hair, cold temperaments to people with brown hair, and equable temperaments to people with tawny hair. He declared that red light stimulated the movement of blood, blue light soothed it.

Amulets and gems have been recorded as having protective and healing power according to color. Amulets were preferred in this order: red, blue, yellow, green, white. Wearing colored amulets supposedly assured health, happiness, prosperity, and protection against the "Evil Eye". Gems are still used in modern hospitals in India according to ancient prescription: crushed and mixed in medicines, these valuable fragments are successful curatives without medical explanation.

The aura of the human being allegedly reveals true character by its color. The human aura is a fine ethereal radiation around the figure, described by Kilner, Bagnall, and others. Red indicates anger, sensuality. Green, blue, yellow indicate benevolence, nobility, intellect. Black and gray indicate malice and fear.

<u>Symbolism of Basic Colors</u>

Yellow: Most luminous but least popular color, particularly the dark hues. Sacred in China and in European Christianity. Yet in 10th-century France the doors of criminals and traitors were painted yellow. Yellow was fashionable from 1890 to 1900 among painters, illustrators, authors, clothiers. However, in days of old, quarantined ships flew a yellow flag, and the terms "yellow dog" and "yellow streak" remain today. Nevertheless, yellow is beautiful when properly used.

Red: Strongest, most attractive color. First color named in primitive languages, and the color most used in primitive classical art (probably to contrast with sky and vegetation). Red indicates danger, rage, strife, courage, virility. In China red symbolized marriage; in the Occident - martyrdom. Red light accelerates the pulse. Red is most popular with women. Bright red is stimulating, but too much is tiring.

Blue: Blue is serene, passive, cool. Spaniards and Venetians of the elite classes recognized the aloof dignity of blue and black in clothing. In the church, blue came to symbolize sincerity and hope. Still used are the expressions "blue-blood" and "true-blue".

Green: Neutral, restful. Green indicates freshness, immaturity. In religion green symbolizes faith, contemplation. The green olive branch is a symbol of peace, the laurel wreath a symbol of immortality.

Purple: Rich, impressive, traditionally royal. Also related to old age.

Violet: The Nineties were known as the Mauve Decade. That era was also the end of the reign of the Dowager Queen Victoria. Violet is retiring, melancholy. Symbolizes women no longer fruitful, or priests in celibacy.

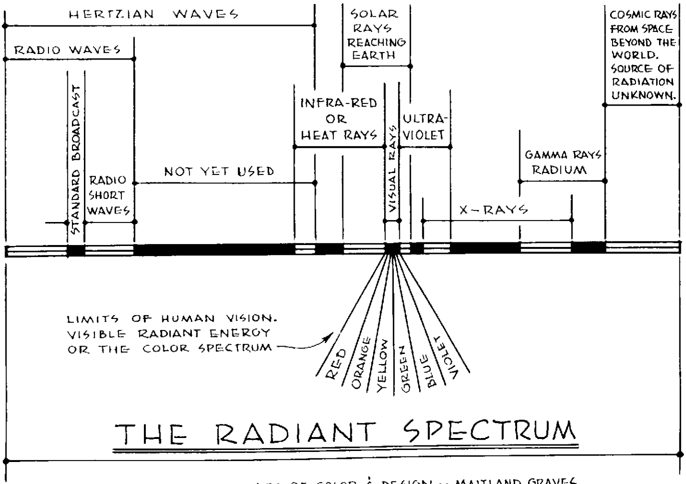
White: Positive, luminous, delicate. Used for weddings in the United States, but signifies mourning in China. Symbol of purity, truth. Also used for surrender or truce.

Black: Depressing, gloomy, solemn. Related to secrecy, terror, death. Expressions: "black hand", "black spot". Yet black can be smartly formal.

Gray: Sedate, humble, negative. Good background for most colors.

It may be concluded that any color can be attractive or repulsive by association or combination. History points out the importance of color to man. The architect must apply the lessons of history and other fields to use color to man's advantage.

PLATE 1




# THE RADIANT SPECTRUM

REFERENCE: THE ART OF COLOR & DESIGN — MAITLAND GRAVES

# P H Y S I C S

## Source of Color

Color is light, which comes mainly from the sun. The eye differentiates kinds of light by their wave-length. Thus color is determined by wave-length. Colored light is the visible portion of radiant energy, which travels through space by electromagnetic waves.

In 1666 Sir Isaac Newton cut a small circular hole in a window shade, directed a sunbeam through a triangular prism, and on a white surface produced the spectrum colors: red, orange, yellow, green, blue, indigo, violet. In effect, each color traveled through the glass with a different velocity, so that each color had a different wave-length. These wave-lengths have been named angstrom units (one one-hundred-millionth of a centimeter), which range from 4000 for violet to 7000 for red. Such wave-lengths can be measured very accurately.

The color spectrum, then, is various visible wave-lengths of radiant energy. Newton showed that these wave-lengths directed through a second prism reproduced white. Thus white is the combination of all colors.

It has been shown that spectra produced through various prisms vary only in the amount of each kind of light, not in the colors.

The rainbow is a synthesis of small spectra of individual drops of water.

Each color is like a musical note - a vibratory phenomenon. Red with its low frequency and long wave-length is analagous to a deep sound, while violet with its high frequency and short wave-length suggests a shrill sound. One sound with half the wave-length of another is an octave higher. Thus we have almost an "octave" of color in the visible spectrum. But the ear can hear about eleven octaves of sound.

Just beyond the ends of the visible color spectrum lie two invisible rays: ultra-violet beyond violet, infra-red beyond red. The color portion of the radiant energy spectrum is comparatively small; a majority of the rays are not expressed in visibility.

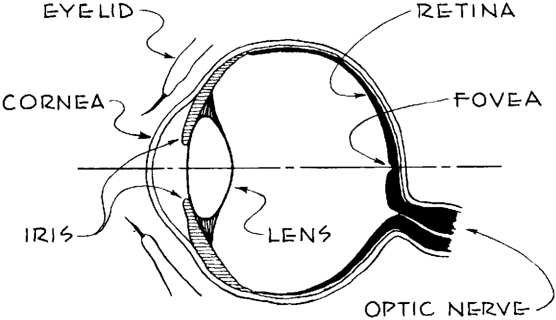
The colors we see depend upon the light source, the reflecting surface, and the resulting sensation. All the colors we see must be in the light source. On a white surface, a red light will show red, since white reflects all the colors of a light source. The fact that the surface appeared white in the first place resulted from its reflection of white sunlight, which consists of all the spectral colors.

Color is produced by addition or subtraction. By addition, blue and yellow light make white light, but by subtraction, blue and yellow pigment make green pigment. Subtraction depends on the chemical or molecular character of pigments, which absorb some light rays, reflect others. Red light on white pigment shows red, but red light on green pigment shows black because green pigment absorbs all red light, and there is no other source light to be reflected. Colors seen under white light may appear only as variations of yellow under an electric sodium vapor lamp. Under kerosene light, bright blue appears brown, while white appears dark orange. A certain sweetpea looks blue-purple in daylight, red-purple in electric light.

Frequent reference is made to the warmth or coolness of color. Physics can attest with a thermopile that red is relatively warm, blue relatively cool, green and red-purple neutral.

The iridescence or opalascence of some colors results from refraction or diffraction due to surface structure. Examples are soap bubbles, oil films, sea shells, ceramic glazes, bird feathers, crystals, gas.

It is obvious that a basic knowledge of its physics is essential to the understanding of color.




# THE HUMAN EYE

REFERENCE: FUNDAMENTALS OF LIGHT & LIGHTING
GENERAL ELECTRIC CO. BULLETIN LD-2

PLATE 2

# PHYSIOLOGY

## Reception of Color through the Eye

The eyes, explained in a short sentence, are much like television cameras.

The smooth, almost spherical outer surface of the eye is called the cornea. A liquid fills the area between the cornea and the crystalline lens. This lens is doubly convex, adjusts its own curvature by its ciliary muscles. The process of adjustment is called "accommodation".

Similar to the iris diaphragm on a photographic camera, the pupil of the eye adjusts the amount of light entering the eye to the photographic speed of the light-sensitive retina. The pupil's diameter varies from two to eight millimeters, the amount of light entering the eye varying in a ratio of one to 20. The intensity of the stimulus may vary in a ratio of one to ten billion, yet the eyes can discriminate a difference in intensity of illumination of only one percent.

In the space between the lens and the retina is a transparent gelatinous substance. The retina is the membrane of the inner lining, has a network of nerve ends called rods and cones. There is a central yellow spot in the retina called the macula, between 1/16 inch and 1/8 inch in diameter. The center of the macula, the fovea centralis, about 1/64 inch in diameter, contains practically all the cones.

Each cone has its own nerve connection to the brain. The rods and the few cones in the periphery of the retina have grouped nerve connections to the brain.

There are about seven million cones in the fovea. Their function is to transmit detail and color. There are about 130 million rods. Their function is night vision.

An image is formed on the retina in inverted position. A replica of the image is correctly seen in the brain, but this replica is not like a photographic image. We see through our eyes, but our brain gives us the picture.

The fibers of the optic nerve to the brain are electro-chemical. The mystery of the process which produces the final image has never been solved.

Incidentally, the eye has a small blind spot where the optic nerve connects.

The cortical region of the brain has a larger area - or more gray matter - devoted to foveal than to peripheral vision, emphasizing the prime importance of the cones in transmitting detail and color. The right side of the brain controls the left side of the body. Corresponding halves of both retinas connect with their own side of the brain.

The eye operates in minute jerks, controlled by three pairs of muscles: one pair for up and down movement, one pair for side to side movement, one pair for line-of-sight axial movement.

Twenty minutes or more are required to adjust to rod vision at night. Man has neither the best daylight vision nor the best night vision of creatures, but he has the best all-purpose vision.

All mammals' eyes are blue at birth - no pigment yet.

Red is aggressive because it tends to focus behind the retina. The lens must bulge to focus it on the retina, making red seem closer. Blue is retiring because it tends to focus in front of the retina. The lens must flatten to focus blue on the retina, making blue seem more distant. These facts account for the vibratory effect between red and blue seen simultaneously. Other colors are relatively neither aggressive nor retiring.

A basic knowledge of the behavior of the eye is seen to be another fundamental requirement in the attempt to understand color.

# P S Y C H O L O G Y

## Effects of Color

Our most remarkable physical skill is that of our eyes, which we train unconsciously but continuously from babyhood. Yet what we see before us is not necessarily what is actually there, but only what our eyes - by association - tell us is there. Our mental pictures are not necessarily shared by others. Each of us may have a different interpretation for abstract objects, without recognizable forms in the same picture to give relation and scale. Something we've never before seen is related to familiar objects by our visual-mental process. In the case of color, we accept all colors without question, as long as the forms related to the colors are known to have such colors.

## Simultaneous Color Perception

Helmholtz used the term "unconscious inference" to explain our ability to see two colors in glossy surfaces. It is debatable whether we see a mixture of the surface color and the reflected color, see both colors simultaneously, or imagine one color continuing across the other. The experience of the individual mind simplifies such complexities.

## Emotional Reactions

Spatial relationships are observed only by the interception of light.

Color is the experience of light, connoting richness and health, satisfying the nervous system.

Color moods may be warm, cold, gay, sad, exciting, relaxing, etc. Psychology tests have indicated that the most exciting colors are deep orange, scarlet, and yellow-orange. The most tranquilizing colors are yellow-green and green. The most subduing colors are violet and purple.

Jaensch concluded from research that people attracted to warm colors are receptive, adaptable to social environment, warm in emotion: extroverts. People attracted to cold colors are the opposite - detached from the world, cold in emotion: introverts.

Bright outdoor light seems to be conducive to muscular activity, while dim indoor light is conducive to mental activity. Kurt Goldstein found that red provides a good emotional background for ideas, green a good background for the fulfillment of ideas.

The theater traditionally relates colors to emotions. The colors of tragedy are gray, blue, purple. The colors of comedy are red, yellow, orange. Red indicates vigor, yellow is for joy and warmth, green means abundance and health, blue stands for spirituality and thought, white is for zest, brown is for melancholy, gray signifies age, and black denotes gloom.

Some interesting experiments have been performed relating colors to sound. Low pitch sounds tend to shift colors seen simultaneously to deeper hues, while high pitch sounds make colors seem more pale. In 1935 Kravkov of Russia studied the effects of sound on the sensitivity of the rods and cones of the eye. He found that sound decreases rod sensitivity, increases cone sensitivity to green and blue, decreases cone sensitivity to red and orange. With sound, then, we see cool colors better, warm colors not so well.

To psychotics and neurotics, whose rational power is limited, color is significant. In the Rorschach inkblot tests, the desire to kill is shown by the choice of red. Feeble-minded persons working with colors use much red, while infantile patients and schizophrenics use much yellow.

The immediate effect of a color stimulus is followed by a reverse effect. For example, the increase in blood pressure brought by viewing red is followed by a slight decrease in blood pressure.

## Analogies and Associations

### Music

The Karwoski and Odbert test of college students showed that they relate slow music to the color blue, fast music to red. High notes suggest light colors, while low notes suggest dark colors. Fortissimo indicates colors which are clear and heavy.

Oswald Spengler assigned colors to musical instruments, calling the horn coppery yellow, trumpets and trombones crimson, the clarinet warm red-brown. Albert Lavignac of the Paris Conservatory compared colors and instruments thus: brown for the bassoon, somber and timid; violet for the English horn, melancholy and resigned; blue for the flute, ethereal and transparent; blue for the strings, seemingly distant; green for the oboe, rustic and crude; white, gray, and black for the percussion instruments, with the triangle silvery.

Sound and color have been compared since Aristotle. In the 16th century Arcimboldo of Milan devised a color scale similar to a music scale. Lavignac related music to painting. Scriabin of Russia in 1911 produced "Prometheus, the Poem of Fire", a musical composition accompanied by colored lights. The first attempt to make a color organ was in 1757 by Castel, a Jesuit priest and mathematician. In the United States, Thomas Wilfred designed the "Clavilux". This instrument presents color patterns on a screen, but no music is incorporated.

## Language

Common phrases are "see red", "business in the red", "red herring", "red cent"; "yellow journalism", "yellow streak"; "greenhorn", "green with envy"; "feeling blue", "blueblood"; "blackmail", "blacklist"; "white" for the vanity of the Caucasian race; and many others.

## Education

University and college faculties in the United States use colors which were assigned in 1893:

| | | | |
|---|---|---|---|
| Scarlet | Theology | Yellow | Science |
| White | Arts and Letters | Purple | Law |
| Blue | Philosophy | Green | Medicine |
| Orange | Engineering | Pink | Music |

## Color Preference

Tiny infants prefer yellow, children prefer red and blue. For children color is more important than form: children given a number of geometric cut-outs of various colors and asked to separate the cut-outs into groups which are "the same" will consider "sameness" to be color rather than shape. Among two-color combinations, children prefer red and yellow or red and blue.

International statistics show that colors are preferred in the following orders:

Men: blue, red, green, violet, orange, yellow.

Women: red, blue, green, violet, yellow, orange.

American Indians and Filipinos place red first. Brunets tend to prefer red, blonds prefer blue. Jaensch states that people in the tropics prefer warm colors because their eyes are accustomed to predominant sunlight, while people in the polar regions prefer cool colors because of predominant skylight. This is a matter of the physiological accommodation of the eyes to certain wave-lengths.

The preference for blue increases with age. The eye lens absorbs more blue as the fluid grows yellowish, making the eye thirsty for blue.

## Harmony

People like either complements (colors which are psychologically directly opposite) or closely related hues. In combinations of light and dark hues, people prefer light variations of hues which are normally light, dark variations of hues which are normally dark:

Use pale green with dark blue, not the opposite.

Use orange buff with deep violet.

Use pink with dark blue or purple.

Use pale yellow with brown, blue, or violet.

Note, however, that nature uses much dark green with pale blue: trees against the sky.

In small areas, pure colors are preferred to shades and tints, but in large areas shades and tints are preferred to pure colors. Incidentally, good diet induces a preference for more subtle colors.

Persons whose color sense is as acute as those of taste, smell, and hearing are the great colorists.

## Basic Color Sensations

The total number of colors which can be seen has been estimated at millions, but in a broader sense there are not so many. Psychology lists four primaries: red, yellow, blue, green. In addition, there are the achromatic colors black and white. Yellow light is a product of red and green light, but the yellow sensation is considered unique.

Tints are hues plus various amounts of white, no black. Shades are hues plus various amounts of black, no white. Tones are hues plus various amounts of white and black.

Ostwald and Katz applied the term "unrelated colors" to hues of light and to film colors, the term "related colors" to surface or object colors. A third type might be termed "volume color" (Katz), exemplified by objects seen through fog.

White has already been explained as a combination of all colors. Black is a color, too, since its sensation is different from a lack of all sensation. Black has low reflectivity but positive effect. Observe that black becomes blacker with more light on it.

The vibration between blue and red is because of different focus. Complementary colors vibrate only when they are of equal lightness, of sufficient purity, and adjacent.

The ear can separate the notes of a chord, but the eye cannot separate the components of a hue. A gray may be composed of black and white or of red and green, but the eye reads only gray.

<u>Other Interesting Phenomena</u>

Highlights seem opaque, but shadows seem transparent. There is a difference in whites, as between silk and cotton.

Blue eyes and red hair are not really as chromatic as they seem.

## <u>Simultaneous Contrast</u>

Colors in combination may change the effect of each other:

Gray looks lighter on black than on white.

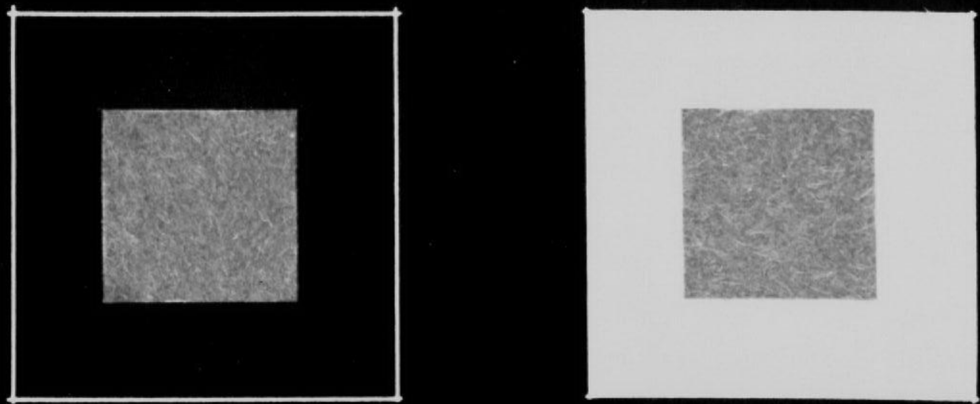
White looks larger and brighter on a dark background.

Blue accentuates the warmth of orange.

Adjacent hues induce their complements in each other.

Strong hues induce their complements in neutrals.

A light, moderate hue is weaker on a black background, stronger on a white background.



## SIMULTANEOUS CONTRAST

GRAY SQUARE ON WHITE BACKGROUND LOOKS DARKER THAN GRAY SQUARE OF SAME VALUE ON BLACK BACKGROUND

PLATE 3

Dark red or blue is weaker on a white background, stronger on a black background.

The strongest contrast in form is obtained by a strong contrast of both hue and value. Stout women can seem slimmer by wearing dark clothes, standing against light backgrounds.

## Constancy of Color

Light itself is rarely seen, but colors tend to remain genuine regardless of light intensity. Memory keeps the sky blue, the grass green, and snow white. White surfaces still seem white when tinted. The color of the complexion seems unchanging despite illumination. This color constancy holds until light becomes very dim. When illumination is decreased, the seeing job is assumed by the rods. Thus colors, which are seen only by the cones of the eye, become dimmer.

Yellow and yellow-green are the most visible spectral colors in daylight, while blue-green is the most visible spectral color in dim light.

Helson tested the effects of colored lights on gray. He found that gray does not change under medium brightness. Under high brightness, however, gray takes on the source hue. Under low brightness gray takes on the complement of the source hue.

## Other Psychological Phenomena

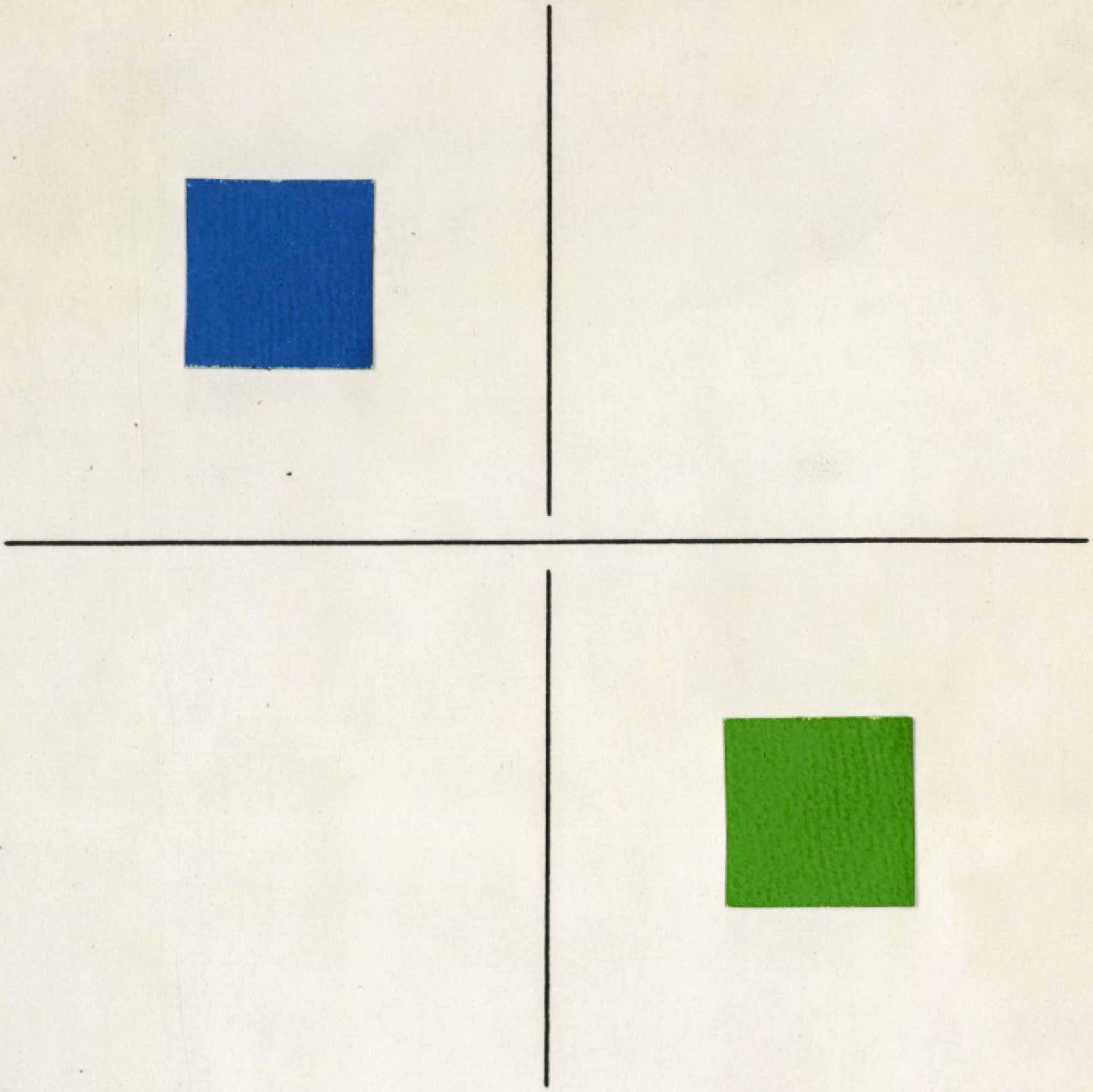
### Color Thinkers

Some people relate colors to vowels or words. For such people, the relationship is established early, in childhood.

## Eidetics

Jaensch lists three types of image: one - the memory, which recollects; two - after-image, obtained by staring at a color, then looking at white (or closing the eyes) and seeing the complement; three - eidetic. The eidetic is between sensations and images and is common to young children. Eidetics may see after-images, but on shorter exposure they may see a reproduction of a hue or an exact reproduction of a silhouette. The eidetic faculty can be induced by drugs or by hallucinations.

Psychology is probably the most important aspect of color to be investigated, since architectural design must aim at psychological function and appeal.



## AFTER-IMAGE

STARE AT EITHER COLOR FOR ½ MINUTE, THEN SEE ITS COMPLEMENT ON BLANK WHITE SPACE

PLATE 4

# P S Y C H O P H Y S I C S

## Relation of Light to Effects

Psychophysics relates physics, physiology, and psychology by establishing laws relating the physical nature of light to its repeatable and measurable effects.

The phenomena here listed, as pointed out by Ralph M. Evans, lie in the field of physiology, but their measurement and specification belong to the subject of psychophysics:

1. Advancing and retiring colors, as red and blue.
2. After-image: staring at a color, then seeing its complement either on white or by closing the eyes.
3. Simultaneous color contrast.
4. Simultaneous contrast by saturation differences of the same color.
5. Related colors. Orange related to white may seem more brown than when viewed alone.
6. Hue shift with intensity. Light on a cylinder may seem to reflect different hues from different portions. A red cylinder may seem orange on its highlight.
7. Spreading effect: opposite of simultaneous contrast. A small area of color seems darker with a black line drawn around it. Example: a colored block letter outlined in black.

Psychophysics studies these and other phenomena from the light source through the reflecting surface to the final image in the brain.

# B I O L O G Y

## Color and Living Things

As late as the 17th century, men knew no more about color than did Aristotle, who considered the primary colors to be white, black, and yellow, which he related to the "elements" of Pythagoras: earth, fire, water, air.

After Newton's experiment with the spectrum, a number of theories were developed concerning color. According to L. H. Hardy, the wave theory, the electric theory of matter, and the atomic theory of energy are all defensible.

Despite his lack of scientific knowledge, ancient man was aware of the value of sun-bathing. Finally, in 1896, Niels R. Finsen made a study of the actinic properties of sunlight, discovered the value of ultra-violet light in fighting tuberculosis. He won a Nobel Prize in 1903.

It has been shown that a continued lack of sunlight causes a sort of hibernation in the human system. On the other hand, too much radio-active energy can be dangerous.

## Plants

For plants, the length of exposure to light seems to be more important than the intensity of the light. The effect of colored light on plants has been studied by Dr. Withrow, who reports:

Long day plants such as the stock grow tallest under orange-red light, then red light, but they neither grow tall nor flower under yellow, green, blue, or infra-red light.

Short day plants such as the cosmos and salvia are retarded in their flowering by red light.

Light has various effects on other plants. In Holland, red neon light is used to assist the growth of flowers and strawberries.

## Invertebrates and Vertebrates

Even the lowly amoeba can be seen to be affected by light, for it adjusts itself as light changes.

Insects gather around blue light, but they are repelled by yellow and red light. Blue surfaces may bring different results: in France it was found that blue walls attracted fewer flies than walls of other colors. A yellow surface may be used for an insect trap. Insect behavior varies too much in various locations for establishing many rules.

The migration and sex activity of birds has been shown to depend more on light than on temperature.

Colors apparently do not affect most mammals; indeed, most mammals are color-blind. Men and apes are exceptions. Color has a physical effect on the human organism, though the medical profession hesitates to accept color therapy.

The protective outer coloring of many animals is well known. Man has adapted this principle of camouflage to his own use, but the objective is quite the opposite of that of architecture.

# COLOR-BLINDNESS

## Differences in Color Perception

Among the various theories of color vision, the Young-Helmholtz theory is the most generally accepted. It states that there are three types of cones in the eye, one type sensitive to red, another sensitive to green, a third sensitive to blue. Work in color vision and color blindness assumes this tri-receptor mechanism.

Color-blindness may be congenital or it may be acquired, but women need seldom worry, for less than one-half percent of women are color-blind, while about eight percent of men are afflicted. Most color-blindness is in the red-green category - that is, reds and greens are difficult to distinguish from each other.

Apes, as well as men, see color, but other mammals are color-blind. The bull is attracted by motion alone, not by color.

Birds and turtles see color, and no fish are known to lack color vision. Insects, however, see no red, only yellow, blue, green, and violet.

Fortunately, color-blindness is not too prevalent among human beings, else this thesis would be in vain.

# A R T

## Esthetics and Application in Creation

Color - a basic human need - is the modulation of light by the structure of substances, subject to shading and shadows. Color sensation has three qualities:

Hue or color, determined by wave-length.

Brightness or value, by intensity of illumination.

Saturation or depth - the color content.

Children at first prefer red and yellow, neglecting illumination and using value only to segregate shapes. Adults prefer red and blue.

Colors are relatively warm or cool. Any color can be made warmer or cooler by mixture with the appropriate neighbor in the color circle. By simultaneous contrast, colors may appear larger or smaller, heavier or lighter, darker or paler, nearer or farther.

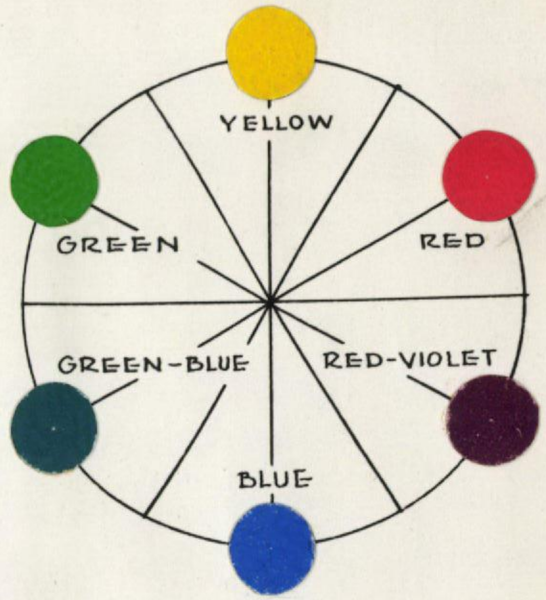
The U. S. Bureau of Standards says there are ten million colors, but no system of color notation presents more than about 1500. The spectrum is resolved into six to ten primary colors following the psychological law of the threshold of optimum discrimination.

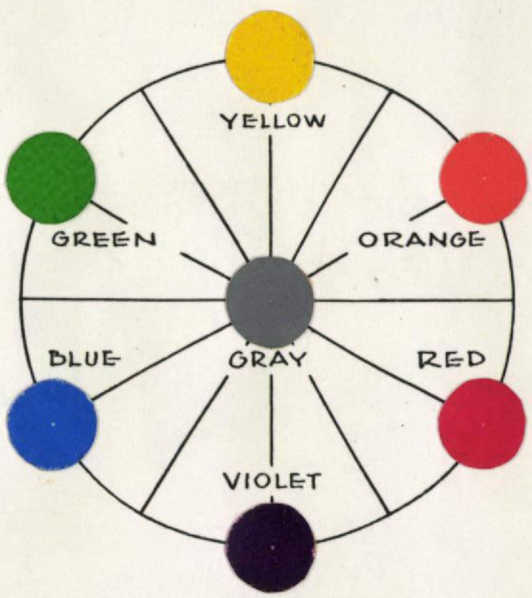
## Complements

Color harmony has been described as the balanced condition of the complementary energies. The potential energy of complements acts in the unconscious mind even when one of the complements is missing from a painting.

## PSYCHOLOGICAL COMPLEMENTS

DETERMINED BY AFTER-IMAGE




## PIGMENT COMPLEMENTS

DETERMINED BY MIXING TO NEUTRAL GRAY

# COMPLEMENTS

REFERENCE: DESIGN FUNDAMENTALS -- ROBERT GILLAM SCOTT

PLATE 5

The common occidental complements are green and red, blue and yellow. These were used by the old painters but were interpreted differently.

Newton mentioned only gold and indigo as being complementary, while Goethe listed yellow and red-blue, blue and yellow-red, purple and green. Ostwald and Munsell, whose color notation systems have been developed for contemporary use, listed these complements as basic:

| Ostwald | Munsell |
|---|---|
| yellow and ultramarine | yellow and purple-blue |
| ice-blue and orange | blue and yellow-red |
| red and sea-green | red and blue-green |
| leaf-green and violet | green and red-purple |
| | purple and green-yellow |

Complements are determined either by psychological after-image or by pigment mixture. Supposedly each pair of pigmentary complements mixes to neutral gray, but this is a subjective test considering the development of scientific colorimetry. The basic complements are these:

| Psychological | Pigmentary |
|---|---|
| yellow and blue | yellow and violet |
| red and green-blue | red and green |
| green and red-violet | blue and orange |

Goethe knew that shadows tend to show the complementary hue of the light source. This principal was used in old stage sets where shadows were painted the complement of the light filters.

## Painting and Painters

Helmholtz said, "A careful study of the paintings of the great masters....is of great importance for physiological optics." Physiological and psychological optics, art, and illuminating engineering are all related, not only to each other but to architecture.

The painter is one of the best researchers by continuous experimenting. He builds space, captures motion, records life, explores color.

Primitives painted with abandon. Color areas were not handicapped. Forms showed local color regardless of illumination. Size and shape ignored perspective. Prior to the Renaissance, painters avoided competition with original effects, used paints for their own organic glow, relating them to each other rather than to realism. Byzantine, Florentine, and Venetian painters of the 14th and 15th centuries used colors in juxtaposition which mixed from a distance - a principle known to Aristotle. Here began the real conquest of color.

The discovery of exact vanishing-point perspective produced a new objective: to obtain a true optical appearance from a single viewpoint. Renaissance painters pursuing perfect spatial illusion used color radiance only as an agent, began losing the power of color. Pigments were used to absorb or reflect only to imitate actual effects. Colors were mixed on the palette from the primaries, red, yellow, and blue. The colors thus obtained by subtraction were darker than any of the originals. Later came mixture by addition or the mixture of the light primaries, red, green, and blue, producing colors lighter than the originals.

The impressionists and the expressionists freed themselves from imitation. Delacroix and others discovered radiance. Radiance was achieved by fine shading, underpainting, transparent varnishing, after-image, and juxtaposition of complements. Painters mixed the palette in the eyes of the spectator - again the principle known to Aristotle. Colors were tested for movement, such as advancing or contracting. The painter became bolder in dissociating color surfaces from objects. According to Gyorgy Kepes, "The color dots of the impressionist painters, through the color facets of Cezanne; the decorative color pattern of Gauguin and Matisse, reached full growth in the work of the cubist and attained a final purity and power in the work of Malevitch and Mondrian."

Cezanne used fine strokes on the canvas to mix color in the eye, achieved depth with color rather than with vanishing points. He showed that black or blue can be made to stand before white.

Juan Gris mixed light brown and black, obtained a hue which suggested violet. He then added violet to the surroundings for a special effect.

Tiepolo avoided common muddy shadows on the face by painting shadows vermilion.

Van Gogh got three values from one hue with thick strokes. His original desire was to give an illusionistic rendering of nature. Instead, he produced a fascinating color and light display.

Renoir juxtaposed red and green, blue and yellow spots.

Seurat set dots close together, achieving vibration and preconceiving the method of color photography, i.e., green and red dots together look yellow. He used color to create symphonies of light, used shapes only to carry light.

Fra Angelo and Botticelli used thin green tones, then many fine red lines to give a saintly effect to flesh.

An old rule was that a painting should be viewed from a distance eight times its diagonal for full effect.

Rubens sketched with brown brush strokes on white, painting over this with a creamy, translucent white. The result was an orange-rose skin tone with bluish transparent shadows. This was called the turbid medium, turbid meaning layers of transparencies.

Contemporary painters employ color in its perceptional impact, thus rejuvinating emotions. Color has been discovered anew as a material of plastic creation.

Optical fidelity to one instant should not limit the spatial extension of a painting, for time cannot be separated from matter. Light and shade can be molded to explain an object without arresting it in time. Values can be controlled so that forms appear to dissolve in the background.

## Composing with Pigment

A good color scheme should be appropriate and unified. Some of the means for achieving color harmony:

1. Reflect balanced amounts and varieties of chromatic light.
2. Satisfy rhythm by repetition of interval.
3. Suggest form, direction, space.
4. Please with similarities.
5. Stir with contrasts.
6. Arouse welcome memories.

Planned color chords should be applied to compositions. First, the light and dark pattern of a composition should be laid out on the drawing in neutral tones. Then a preliminary overlay should be made in color, taking care to develop parts simultaneously.

It is necessary to know the behavior of pigment, for changing the value of a chromatic pigment also changes its hue and chroma. Yellow plus black gives a greenish shade. A bit of red could be added to counteract the green, but a simpler solution is to use raw umber instead of black.

Hues are developed by subtractive mixing, for pigments reflect related wave-lengths. Ostwald called the composite sensation "semi-chrome". The primary pigments are red, yellow, blue; the secondary pigments are green, orange, violet. Adjacent hues have maximum semi-chrome consonance. The most consonant triad interval is red-yellow-blue.

When a color circle is organized on the basis of the primaries and secondaries, the basic harmonies are complements, triads, and analagous hues. Another harmony is the split complement, a triangular relationship located between the complement and the triad.

Yellow and blue pigment make green, but suppose we list four different yellows and four different blues:

| | |
|---|---|
| cadmium yellow light | cobalt blue |
| cadmium yellow medium | ultramarine |
| yellow ochre | cerulean blue |
| raw sienna | phthalocyanine blue |

Combinations of these will give no less than 16 greens of different hue, value, and intensity.

Intensity of a hue may be changed in four ways: by adding white, black, gray, or the complement:

Hue plus white gives tint.

Hue plus black gives shade.

Hue plus gray gives tone.

Hue plus complement gives neutral gray, e.g.:

ultramarine plus burnt sienna

cadmium red plus chromium oxide green

A composition may be keyed high, low, or medium on the value scale. A high key means light tones. Hue keys are difficult to organize because hue cannot be separated from value and intensity except analytically.

The most exact scientific hue circuit is that of Ostwald. It is good for color standards but not well fitted to the mixing of artists' pigments. The artist's pigment color circle is set up to produce neutral gray with complements, so analagous ranges are not as uniformly spread as in the circles of Ostwald and Munsell.

Robert Gillam Scott warns that in designing you should "base your use of complements on the true psychological complementaries".

Practicing with a limited palette will increase color understanding. Try tonality toward one hue or one temperature. It is best in any case to limit the hues which are the basis of a color scheme. Great art shows, very often, a selection of three basic hues. Witness:

Persian miniatures and rugs.

French and Flemish tapestries.

Paintings by Gauguin, Van Gogh, Monet, Brangwyn.

Italian Renaissance walls and ceilings.

Windows of Chartres, Amiens, Sainte Chappelle.

## Colored Light

To compose with light and pigment together, new research is necessary. As Moholy-Nagy said, "....this is not yet the age of light painting. It is only the hour of light advertising, serving publicity, to catch the eye." Our age is characterized by the "craze for raw speed" and by "blind motion".

The painter must know both the old craft and the new colorimetry, for the physiology of the eye is more closely related to the pure light of the spectrum than to crude pigment mixtures.

Moholy-Nagy recommends more experimenting with polished surfaces, translucencies, pigments, and various kinds of light.

All of these principles concerning the use of color in art are of considerable importance to the developing architectural designer.

# P H O T O G R A P H Y

## Another Art Related to Color

Photography made obsolete the painter's goal of illusory representation. Now an infinite variety of brightnesses could be recorded. Renaissance artists had simply blurred distant objects. Photography provided a means for extensively studying relative clarity.

In color photography, the chemical emulsion yields only artificial coloring so that photographs have a boringly unifying complexion. Some additional distortion may be produced by the projector light. For best results, the photographer should understand painting as well as the peculiarities of his own medium. The real beauty of the photographic apparatus is that it can capture fleeting light and reflections.

## Abstract Films

Pioneer of abstract films was cubist painter Leopold Survage, who in 1913 originated the technique of master drawings with fill-ins on celluloid. Prodigious labor was involved: at 24 frames per second, a ten-minute film required 14,000 frames, each drawn and colored by hand. Not till 1919, however (because of the war), did the first non-representational film appear: "Diagonal-Symfonie" by the Swedish artist, Viking Eggeling, in Berlin. Additional works followed by Richter, Ruttman, and others. The first in the United States was by Maude Adams (of Peter Pan fame): "Color Dynamics", produced by Eastman in 1925. Subsequently, many films were synchronized to famous music.

Moholy-Nagy anticipates an "optofonetic" art: see music and hear pictures simultaneously. The first steps are through photography, cinema, and television.

# SYSTEMS

## Color Notation

"It is significant that the world's greatest music has been composed since the perfection of a system of musical notation," says Maitland Graves. The inference is that the perfection of systems of color notation has opened the way to the world's greatest color-use.

Color depends on the source of light, on modifiers of that source, and on the observer for full effect. Condensed, this gives Foss's formula: "Source x Modifier x Visual Process equals Color." Color may be specified without reference to material, but material must be considered in order to develop samples for a color notation system. Indeed, the stability of the reference, or sample, is the primary objective.

There are three methods for deriving colors:

1. Mixing colorants to show their gamut.
2. Mixing colors by disks, etc.
3. Selecting colors visually for equal spacing.

## Colorant Mixture Systems

Colorants are pigments or dyes as used in paints, papers, plastics, and fabrics. Color is only one property of colorants; the others are physical or chemical. Colorants are measured by weight or by volume. Ease of manipulation makes paint a widely used colorant.

There are thousands of colorants, but a relatively small number is used to produce a collection of samples for a color notation system. For paint, a colorant ("selective modifier") is called a toner and is commonly shown in its range of combinations with white ("non-selective modifier") to illustrate its main coloration possibilities. If the proportional mixtures for this range, or gamut, are based on an arithmetic scale, a preponderance of dark colors will result, but a logarithmic scale will give a preponderance of light colors.

With a complete set of samples to illustrate a gamut, three-dimensional presentation is necessary.

## Plochere

The Plochere system uses ten basic oil paints to produce 26 series of mixed base paints, each series ranging from near neutral to full chromatic hue in six steps. Radially arranged, this gives a circular formation of 156 colors. This is the base of a cylindrical color solid, developed further by adding white in eight steps to each base paint. The total is 1248 samples. For practical reference, these samples are presented on three by five-inch cards, each with the formula on the back.

The purpose of the Plochere system is to provide a relatively inexpensive collection of samples showing practical formulations for paints actually on the market.

The Baumann system is similar to Plochere.

Martin-Senour

The "Nu-Hue" system of Martin-Senour uses six chromatic and the two achromatic colorants. There are 1000 samples arranged hexagonally in a conical solid. The base has a black center, white being added toward the pure white peak. This is a strict application of prescribed mixtures, with no deviations for visual considerations. The company presents the samples on three by five-inch cards with formulas.

The purpose of the Martin-Senour system is to provide a precision formulation technique for production of paint in quantity to match given colors, mostly for interior wall finishes.

## Color Mixture Systems

Mixing of colors means additive mixture of source colors, unlike subtractive mixture with pigment colorants. Color mixture is accomplished by:

1. Spinning disks.
2. Half-tone screening in printing.
3. Stippling, as by artists.
4. Combining spotlight colors on the stage.

Color mixtures based on an arithmetic scale give a preponderance of light colors. A geometric scale gives dark colors. The case was the opposite with colorant mixtures.

The usual pattern for developing varieties of a single color is triangular, with the hue at one corner, black and white at the other corners, combinations between. With all the hue triangles together, a double-conic solid is developed.

## Ridgway

The Ridgway system offers 1115 samples. Here is a double-conic solid with pure colors at the equator, tints above, shades below. The system, published in 1912 , has been used extensively in the horticultural and biological sciences. Unfortunately, there is some indication that the actual samples tend to follow colorant gamuts rather than the theoretical disk mixtures reported by Ridgway.

## Ostwald

The Ostwald system, developed in the early part of the century by Wilhelm Ostwald, uses a double-conic solid. The equator hues are based on psychological complements. Triangular hue planes are set radially around an axis which extends from white above to black below. Mixture ratios are determined by logarithmic scale for visual reasons. In 1942 the Container Corporation of America produced Ostwald charts in its "Color Harmony Manual", with 680 samples, each with one dull and one glossy surface.

Ostwald assumed these fundamental color sensations:

Achromatic: white and black.

Chromatic: yellow, red, blue, green.

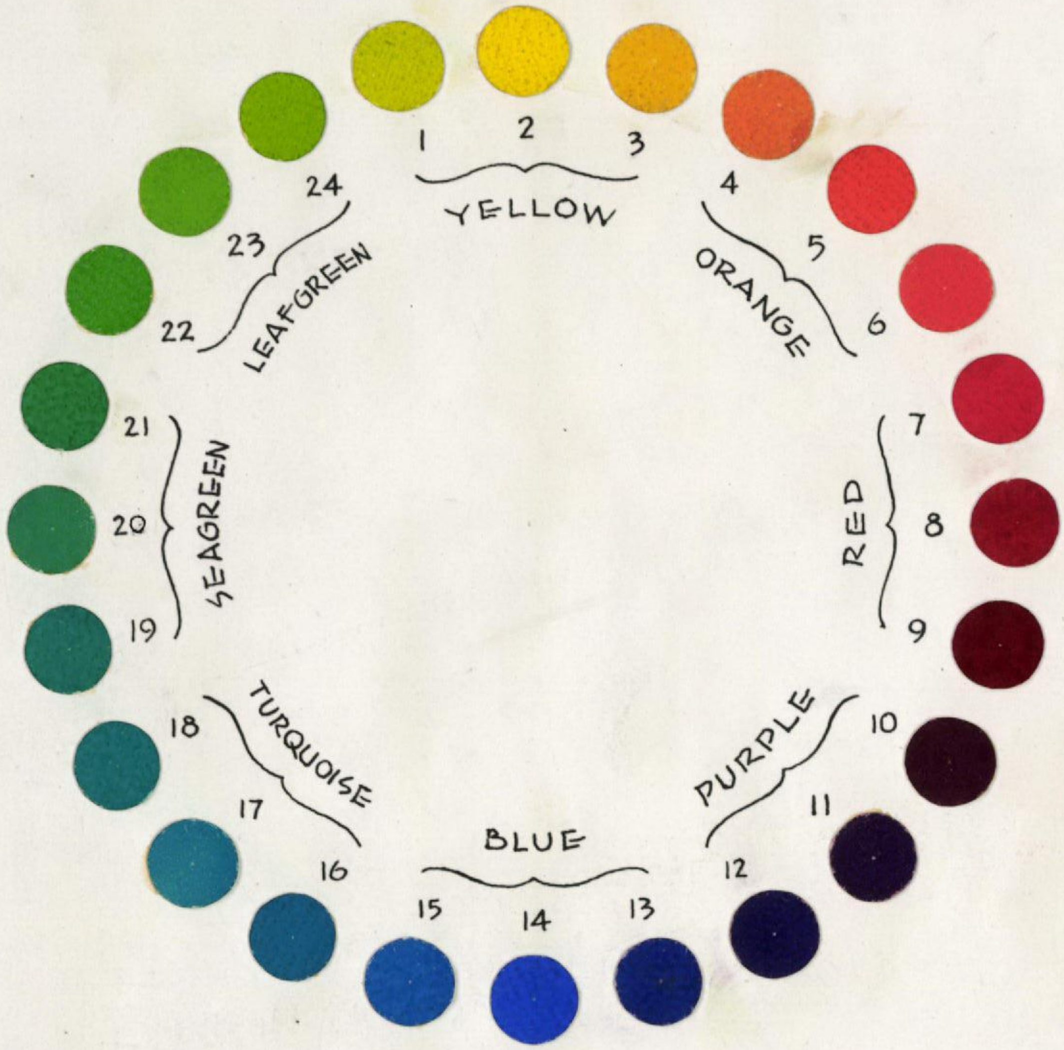
The true green sensation is assumed to be unique - not yellowish, not bluish. However, orange is assumed to look both yellowish and reddish; purple is assumed to look both bluish and reddish; and gray is assumed to look both whitish and blackish. The blue and yellow are complements as determined by after-image; likewise, the red and green.

Ostwald's four primaries: blue, yellow, red, seagreen. The four secondaries: purple, leafgreen, orange, turquoise. With additional in-between hues, a color circle of 24 hues is presented. Each hue is identified by a number.

A triangular hue plane is developed with each equator hue and the white-to-black axis. The series ranging from full color to white is called the "light clear series". The series ranging from full color to black is called the "dark clear series". Lower-case letters (skipping some for later subdivision) label the axis from white to black, with "a" for pure white and "p" for pure black. Conversely, "a" means no black, "p" means no white. The notations in the light clear series and in the dark clear series, also in the remainder of the triangle, indicate the relative amount of white (first) and black(second). Thus, "na" means a little white, no black; "pl" means no white, much black; "ig" means a medium amount of both white and black; "pa" means no white, no black, which is the full color.

The full notation for a single hue consists of its number plus the two lower-case letters indicating white and black content. A light tone of seagreen might be "20 ic".

Each series of colors is based on the Weber-Fechner law, which states that the sensation of equidistance between members in a series is produced by stimuli arranged in geometric progression. Geometric progression here applies to percentage of light reflection.

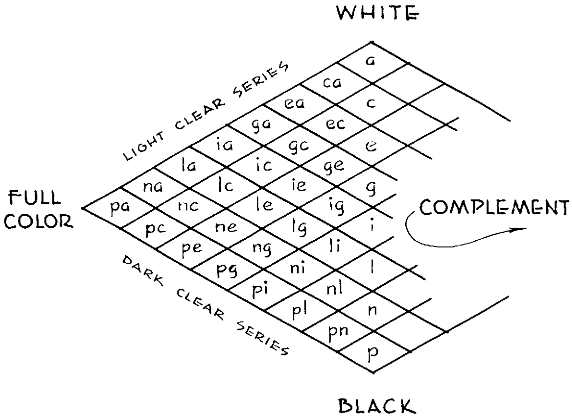


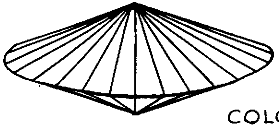

# OSTWALD FULL COLORS

(APPROXIMATE)

REFERENCE: BASIC COLOR – EGBERT JACOBSON

PLATE 6



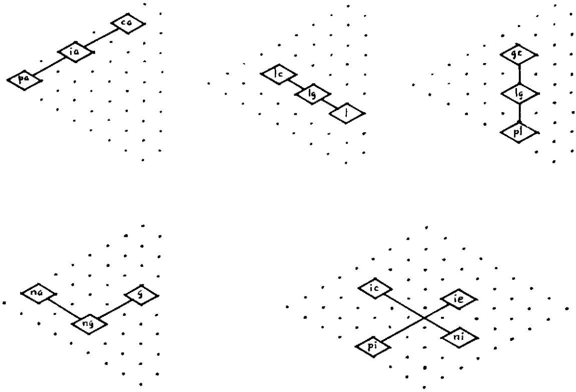



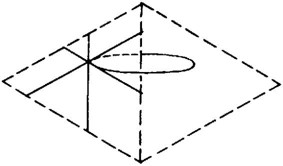
COLOR SOLID

# OSTWALD DETAILS

REFERENCE: BASIC COLOR - EOBERT JACOBSON

PLATE 7



THE RING STAR

# OSTWALD HARMONIES

REFERENCE: BASIC COLOR – EGBERT JACOBSON

PLATE 8

In a hue triangle, "F" stands for full hue, "W" for white, "B" for black - these at the three corners. The vertical rows in the triangle parallel to the W-B axis make up the "shadow series". The diagonal rows in the triangle parallel to the F-B line make up the "equal-white series". The diagonal rows in the triangle parallel to the F-W line make up the "equal-black" series. "Equal-white-and-black circles" are all the circles parallel to the equator, since in any circle the white-and-black content of each hue is the same.

## Harmony

Ostwald's hue circle is based on psychological complementarism. The gray scale is based on the Weber-Fechner law. With the entire double-conic solid thus carefully organized, harmonious combinations are not at all difficult to select. The rule for simple harmonies is equal spacing between three hues. More complicated harmonies involve various equal intervals. Basic examples:

Three grays equally spaced on axis; sequence immaterial.

Monochromatic harmonies:

- Three hues in equal-white series equispaced.
- Three hues in equal-black series equispaced.
- Two hues plus one gray, triangularly equispaced.
- Other combinations involving light-clear, dark-clear, shadow series, and grays - all based on equal intervals, whether in line or triangular.

Two-hue harmonies:

Equal-white-and-black pairs by circular division.

Transverse complements, by diagonal slice.

Three-hue harmonies:

Equal-white-and-black triads by circular division.

Splitting, or changing intervals.

The "ring star" is Ostwald's name for a figure which produces a large number of harmonies based on a single hue. For best example, select a hue within a hue triangle containing both white and black. Through this single point draw three lines and one circle: one line in the shadow series, one line in the equal-white series, one line in the equal-black series, and an equal-white-and-black circle. These three lines plus the circle form Ostwald's "ring star", from which we may obtain 35 colors to harmonize with the original. The principle of equal intervals applied to the ring star gives a seemingly endless variety of harmonies for a single original hue.

Egbert Jacobson, in explaining the Ostwald system, points out that a color combination may be selected visually, then checked against the ring for harmony.

The Ostwald system has been successfully checked against the paintings of great masters who worked without such a system.

Here, then, in this system of color notation, we have a truly scientific means for designing with color.

## Colorant Mixture and Color Mixture Combined

### Maerz and Paul

The Maerz and Paul "Dictionary of Color" was produced by printing methods - by half-tone screens, a process which is really both colorant mixture and color mixture. The dictionary contains several thousand colors derived from eight chromatic inks. The purpose of the dictionary is to provide an authority on color names.

## Visually Spaced System

The objective here is to achieve uniform spacing of colors in a system by eye. Such a system is not based on equal weights or volumes as in the colorant-gamut system, nor is it based on equal areas of color as in the color-mixture system. In a visually-spaced system, a geometrical solid is no longer possible.

### Munsell

The Munsell system, developed by Albert H. Munsell from 1900 to 1912 in Boston, is based on three unique attributes of color:

Hue, or name.

Value, or degree of lightness or darkness.

Chroma, or degree of departure from gray of same value.

Munsell established five major hues, equally spaced on the color circle: red, yellow, green, blue, purple. The five secondary hues:

yellow-red, green-yellow, blue-green, purple-blue, red-purple. This ten-step notation is further divided into 100 steps.

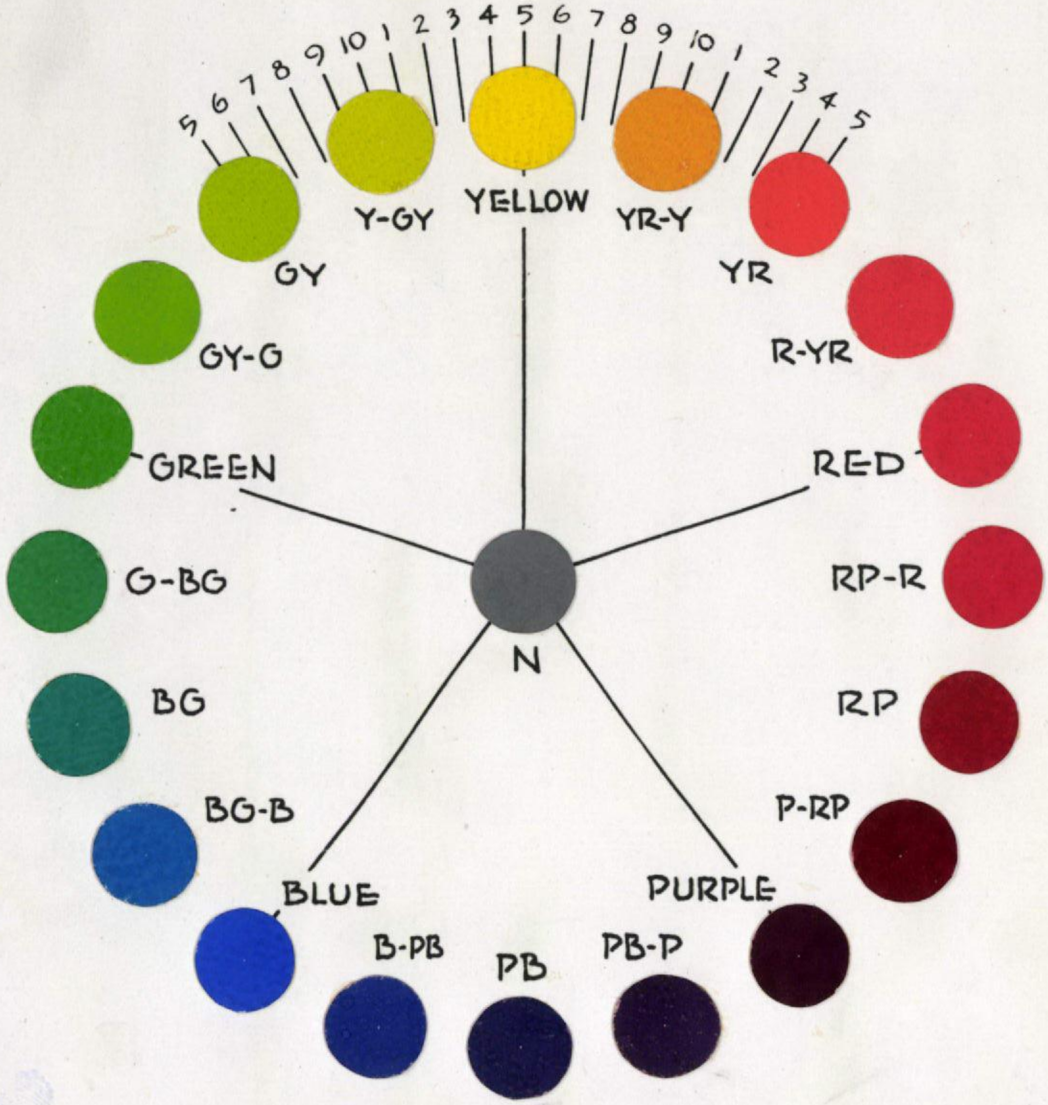
Each hue is noted either by capital letters or by letters plus a number. The letters are the initials of the hue; the numbers indicate intermediate hues. For example, "3RP" is red-purple which is slightly more purple than red. "RP" is exactly red-purple.

These hues form a basic color circle in plan, but this circle does not become an equator. The solid is irregular.

The Munsell value scale is a vertical axis ranging from zero for black to ten for white. Since these numbers indicate theoretically pure black and white, the practical scale is limited to numbers from one to nine. The value scale, just as the hue scale, is visually equispaced so that all intervals appear to be equal. The value notation is a number following the hue letter and followed by a slant, as "3RP 4/". Following the slant comes the chroma number.

The chroma scale ranges from zero for gray to ten for full chroma. Vivid colors may have a chroma of 15 or 20. With the chroma number, a complete notation might be "3RP 4/7", which is 3RP of slightly dark value but fairly strong chroma.

Thus the solid is irregular: constant hue planes of various shapes radiate from the central vertical axis, each plane with its own range of values and chromas. Horizontal slices give constant value charts. Core cuts give constant chroma charts. Geometry is sacrificed for important visual equispacing. In the new Foss modification of Munsell, samples are illustrated equispaced in all directions.

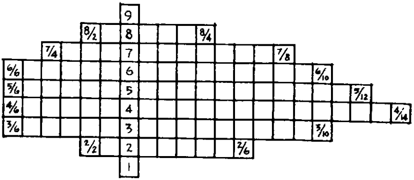



# MUNSELL PURE HUES

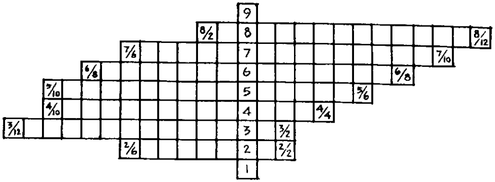
(APPROXIMATE)

REFERENCE: THE ART OF COLOR & DESIGN — MAITLAND GRAVES

PLATE 9




RED & BLUE-GREEN
(COMPLEMENTS)




YELLOW & PURPLE-BLUE
(COMPLEMENTS)

## MUNSELL CONSTANT-HUE CHARTS

VERTICAL CROSS-SECTIONS OF SOLID. BOUNDARIES ARE IRREGULAR BECAUSE INTERVALS BETWEEN COLORS ARE EQUAL IN BOTH VALUE & CHROMA.

REFERENCE: COLOR ORDER SYSTEMS — CARL E. FOSS
REPRINTED IN A.I.A. 1949 CONVENTION SEMINAR ADDRESSES ON COLOR

For paint-mixing, Munsell is not the most useful system. For calculating color mixtures, Munsell is not the most convenient system. But, as Dorothy Nickerson says, "To describe color as we see it, the visually equispaced scales of the Munsell system are by far the best choice to make to provide both an understanding of color space and a simple and satisfactory notation for describing color perceptions."

The value scale may be used to judge color by eye as to lightness or darkness. Value can be converted to reflectance for engineering use. The value scale remains valid regardless of the illuminant (tungsten, fluorescent, or colored light), since neutral gray doesn't change.

The Munsell system is applicable in ceramic plants, in paint factories, and in illumination research - used to match, select, and specify color.

In research, results can be clarified colorimetrically either by conversion of Munsell to I.C.I. (International Commission on Illumination) Standards, or by conversion of spectrophotometric work through I.C.I. Standards to Munsell. Spectrophotometric tri-stimulus (source, substance, sensation) data have been converted to Munsell hue, value, and chroma by the Color Measurements Laboratory, M.I.T., under Hardy; by the Colorimetry Section of the National Bureau of Standards; by the Newhall Subcommittee of the Optical Society of America (1943).

Munsell is used by the U.S. Department of Agriculture, by the Encyclopaedia Britannica, by the International Printing Ink Corporation, by Lakeside Press, by Fortune Magazine, by Walt Disney, etc.

## Comparison of Ostwald and Munsell

Ostwald is a color-mixture system based on after-image complements and a geometric solid. Munsell is based on visual equispacing and the inter-relation of hue, value, and chroma. Ostwald considers complementarism more fundamental than perceptual equidistance in the pursuit of harmony. Munsell considers visual equal intervals between the three attributes of color most important. Each system has considerable merit, also some disadvantage.

It must be noted that visual results are not truly the property of the scale used but rather depend on the physical behavior of the colorants used to provide the samples for a color notation system.

With such precise color notation systems in use, and with the daily advancement of the science of colorimetry, color is no longer a guessing game but a practical business which no architect can afford to ignore.

# F U N C T I O N

## The Application of Colorants and Colored Materials

"Color as selected" is a poor architectural specification, since it implies last-minute selection. It is a "pathetic fallacy that color is a skin to be stuck on, not an integral element of architecture", says Julian E. Garnsey. "Well-planned color, like good salad dressing, brings an inspired solution in form to perfection and may even rescue a less-than-inspired design."

The architect should know both color and the physiological and psychological make-up of human beings. It is necessary to be thoroughly familiar with public preference and prejudice. To begin with, it should be realized that folk and peasant art are quite honest and influential in color development.

## Visibility

Sunglasses should be yellow or yellow-green.

Light signals are best seen when red, then yellow, green, white; not blue or purple.

Yellow is the most visible color if a single color alone is considered for both light source and paint.

Both signs and posters are most legible in this order: yellow and black, green on white, red on white, blue on white, white on blue, black on white (sixth).

For backgrounds for legibility, green is not so good as popularly supposed. White is best. Yellow, yellow-orange, or yellow-green - all in tints - are all right for backgrounds for reading.

In an experiment to select suitably legible instrument dials for the Navy, it was found that in strong light, white figures on a black background were best, while in weak light, black figures on a white background were best.

A study of visibility leads directly to brightness engineering. As stated by M. Luckiesh, "A visual task is inseparable from its environment." The common error is to put too much brightness in a room for the sake of high footcandle readings. If an extreme contrast exists in the same field of view, the general lighting level of an interior must be held down. More about this under the heading, "Illumination".

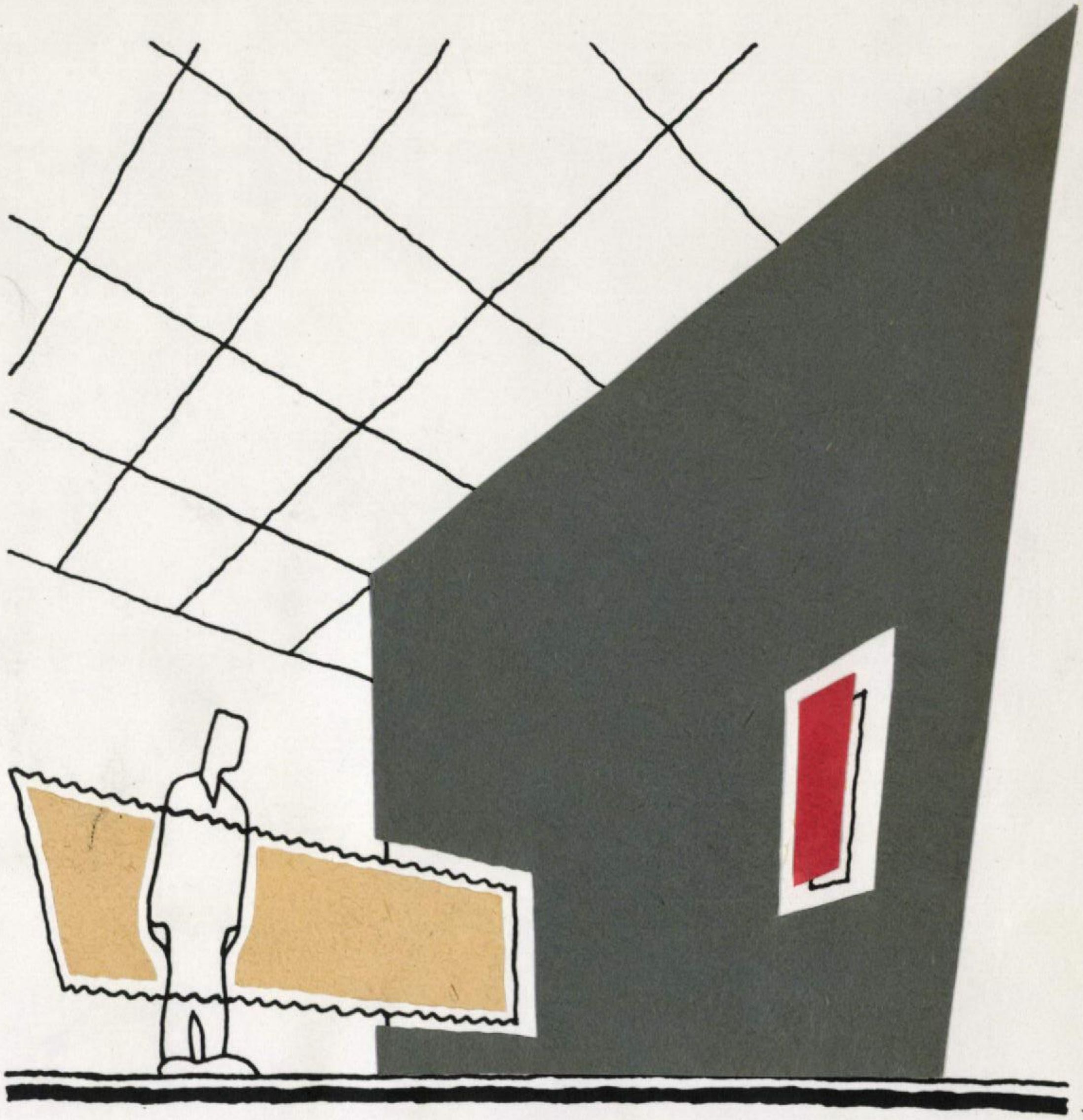
## Principles of Planning

There are three basic color relation patterns:

1. Monochromatic
2. Analagous
3. Contrasting

The optimum scheme, as attested to by great works of art, is limited to three basic hues.

People like only a small amount of a bright accent hue, a medium amount of a medium relief hue, and a large amount of a dominant grayed hue. Remember, however, that color is not to be avoided by refuge in neutral grays. Neutral grays are laboratory products seldom found in



PEOPLE LIKE....

A LARGE AMOUNT OF A DOMINANT, GRAYED HUE,
A MEDIUM AMOUNT OF A MEDIUM, RELIEF HUE, &
A SMALL AMOUNT OF A BRIGHT, ACCENT HUE.

PLATE II

practice. Besides, neutral gray is timid and indecisive. Grays usually require much study for the proper tinting.

Colors can be used to excess in variety and pattern, but monotony is more likely to drive you crazy than excess variety.

Color combinations should, of course, take advantage of the visual phenomena: simultaneous contrast, after-image, advancing and retiring colors, irradiation. The New York World's Fair of 1939 was intentionally "souped up" to compete with the greatest show on earth - New York City. At the Fair, Garnsey made a particularly effective use of after-image involving the Long Island Railroad Station. He glazed the Railroad Station with blue-violet so that visitors coming from the Station to the Fair would receive the after-image of yellow. This after-image was powerfully magnified by the sudden view of the "Golden Circle" feature of the Fair. This "yellow-upon-yellow" effect inevitably brought an exclamation of delight from each new visitor.

## Application

In architecture, color studies should be well-thought-out abstract diagrams.

For exterior studies, it is necessary to consider:

1. Purpose of building.
2. Geographical location.
3. Surrounding buildings and landscape.
4. Climatic conditions.

The preliminary study should relate tones to establish light and dark patterns. This study should then be taken to the site of the proposed building, where basic colors should be chosen by observation of the area under various conditions: bright sunlight, overcast, evening.

The inspection of color chips is not enough to select building colors for a particular site. Consider differences such as these:

San Diego: violet mountains and blue sea

Dubuque : rolling hills

Denver : black and green Rockies

Dallas : flat, varicolored plains

Obviously, different colors are suitable in different areas. Note the sensitive reaction of Frank Lloyd Wright to environment.

Even when colors of materials have been selected, it is necessary to observe sizable areas of these colors actually put up on the site. A trial wall of several square feet of brick might be put up beside a trial wall of several square feet of cement-asbestos siding to observe the color combination. A painted surface might be included with these, depending on the specifications for the building. Again, when actual construction of the building is under way, colors should be observed so that changes can be made if necessary. Naturally, it is wiser to decide on masonry colors first, then adjust the colors of lighter materials to the masonry colors. Paint is easiest to change, but the color decision should be made as early as possible to save money.

Alas, not even the completion of the building with perfectly satisfactory colors concludes the test. The element of time has yet to act. The architect would do well to investigate fading and other color changes in materials brought about by time and the elements of the particular region.

For interior color selection, it is necessary to consider the function of each building type. (Interior and exterior, however, are often scarcely separable in the thoroughly functional design of today.) Warm hues are best used in elementary schools, hospital convalescent rooms, and recreation rooms where activity is largely physical. Cool hues are best in secondary schools, hospital chronic rooms, and study rooms where the emphasis is on mental activity.

In interior decoration, strong chromas may be applied to reception rooms, foyers, and bars, while weak chromas should be used in rooms of long occupation. Harmony may be achieved by repetition of hue. Even the color of paintings should be related to rooms. In northern exposures with the blue-white light, warm colorants are best on walls and furniture. Faber Birren considers peach the most appetizing color for walls in homes. (I have not been able to agree.)

## Public Structures

### Schools

Elementary schools should feature warm, stimulating colors such as yellow, peach, pink. Secondary schools, where concentration is the objective, should feature tones of green, blue, gray. Of course, there are various functions within each school type which call for various color treatments.

## Hospitals

Hospital lobbies should be decorated in a variety of tones to avoid any moods. Maternity areas are suitable in peach and rose, but chronic areas are best in blue, green, gray. In surgery, green and green-blue are wise to counteract glare and the bright colors of operation. Hospitals should avoid lavendar, cool yellow, and yellow-green, which here seem to have a nauseating effect.

## Theaters

Color has extensive application in all theaters. Colorants in combination with light sources are used for fascinating mobile sequences. "Black light" sources supply ultra-violet radiation to specially treated fluorescent materials. Lighting adds delicate tints to selected carpets, carefully planned wall designs, and costumes.

## Other Examples

At a certain rest hotel, blue and white flowers were found to attract more customers than red flowers in the garden. Here we tie in landscape architecture, which is never separable from good architectural planning.

On a certain black bridge which had always attracted suicides, green paint brought a decline in self-destruction.

## Transportation

Airplanes and ships may be treated with moderately warm tones to provide relief from blueness of sky and sea, yet light blue, blue-green, and gray help counteract nausea. Some rather subtle combinations seem to be in order.

## Commercial Use

### Market

Blue-green provides relief from the task colors when applied on the walls of a meat market.

### Clothing

Warm colorants and colored lights are used to present summer sports clothes, while cool colorants and colored lights are used in fur salons.

### Jewelry

Jewelry has been found to be most attractive when presented on strong purple and yellow.

## Office and Industry

For offices and industrial areas, grayish hues are best. Cool colors should be used in high-temperature areas, warm colors in vaulty, chilly areas.

Corridors and stairwells may be tinted yellow. Storage areas are best in white. Washrooms and cafeterias are successful when done in blue for men, rose for women.

## Work Rooms

Suggested tones and reflectances for work rooms:

Ceilings should be generally white with a reflectance of 75-80%.

Upper walls are good in light green or light buff with a reflectance of 50-70%.

Lower walls may be dark green or dark buff with a reflectance of 25-40%.

Floors should have a reflectance of 25%.

Machines and desks go well in medium green or buff with a reflectance of 25-40%.

Bright walls are not flattering to human appearance, though end walls may be given a pleasing tint for psychological relief from neutral tones. Window sash should be light to lessen the contrast with the bright outdoors.

In a certain windowless building, three tones of gray were used on the side walls, with interesting relief provided by coloring one end wall blue, the other yellow.

On machines, avoid black and gray. Light gray and buff have improved both the efficiency of machine operators and the housekeeping in plants (pride in equipment).

## Safety

The 1944 safety code colors developed by Birren and Du Pont were largely incorporated into the Safety Code of the American Standards

Association. The colors and their meaning:

Yellow and yellow-and-black bands are to warn against strike-against, stumbling, and falling hazards.

Orange is for cutters, rollers, switch-boxes.

Green is for first-aid equipment.

Red is for fire-fighting equipment.

Blue is for caution, equipment for repair.

White, gray, and black are for traffic control and housekeeping.

The use of this code has brought about a tremendous reduction in accidents.

The National Industrial Conference Board and the U. S. Public Health Service attest to the value of color programs in industry. The medical profession, too, is studying the industrial aspects of color.

## Medicine

A new therapy is possible with color. There is a need to combine the efforts of the biologist, the ophthalmologist, the psychiatrist, and the psychologist. As Faber Birren says, "The intimate role which color may play should become increasingly vital as man turns from an esthetic and esoteric attitude to one more rational and clinical; as recognized medical science forgets its prejudices and appreciates that color is physiologically and psychologically beneficial and may be put to effective human service."

## Art

The artist, meanwhile, feels the necessity for balancing the technical, scientific approach to color with pure, instinctive feeling for color.

### Color Effects by Hue

Yellow: Cheerful, highly visible. Avoid dark tones.

Red: Dominant, dynamic. Influences hormonal activity, raises blood pressure. Good environment for the creation but not the execution of ideas. Too much pure red is annoying.

Blue: Opposite effect of red. Not successful in offices, industry, schools, hospitals, except in incidental areas in medium or dark tones. Pale blue bothers the eye. Yet blue is the favorite of all colors.

Green: Yellow-green is neutral; blue-green goes with peach, is peaceful, makes a flattering background for the complexion.

Orange: Preferred as peach, salmon, brown. Appealing in food. Flattering to the skin.

Purple: Strictly esthetic.

Black: Negative, perhaps sinister.

Gray: Passive.

White: Natural, clean.

Much of the better architecture of today is good in form but weak in color. One has only to look around. Even architects with reputations as good designers sometimes pay too little heed to the colors of their creations. If an architect or a firm of architects simply lacks a discriminating color sense, the wise step is to get together with a good colorist.

# ILLUMINATION

## Brightness Engineering

"Eyestrain" should really be called "ocular fatigue". The eyes are not abused by overwork - in fact, vision is actually improved by using the eyes. But the eyes may be harmfully exposed to stimuli which impede the normal visual function.

Eye defects are more common among backward children than among "bookworms". Eyestrain may be caused by illness, by poor diet, by critical seeing tasks, by glare environment, or by insufficient illumination. The eye struggling to adjust suffers "eyestrain". There is some indication that extensive eyework contributes to heart trouble.

## Principles of Seeing-Comfort

For seeing-comfort, there must be illumination of the proper color and quality on the work at hand and on the surroundings. The working environment is divided into:

1. Task zone, including immediate surroundings.
2. The rest of the room.

Background, glare, and shadows must be considered.

Color differences in objects are related to reflectance differences. The appearance of a colored object depends on its color, the character of its finish, and the attributes of the light source: color, intensity, direction.

The proper engineering of lighting is important because many workers spend two-thirds of the day on close work.

## Light and Lighting Fundamentals

Photometry is the science of measuring light. Photometric data are used by the illuminating engineer in choosing equipment, lamps, wall finishes, color of light, and color of background. Extensive charts of photometric data are available.

### Terms

The terms used in measuring light are based on the relationship existing when a one-candle-power source is assumed to be at the center of a hollow sphere with a one-foot radius:

"Point source" is the term for the source described.

"Lumen" is the luminous flux radiated from a one-candle-power source to each square foot of area. The area of the basic sphere is 12.57 square feet, so one candle equals 12.57 lumens.

"Mean spherical candle-power" is the average of all candle-powers in all directions about a source.

"Foot-candle" equals one lumen per square foot. Illumination on a surface is measured in lumens per square foot. The unit sphere has an illumination of one foot-candle.

Inverse square law: for a given point source of light, the level of illumination decreases as the square of the distance from the source.

Foot-candles equal candle-power divided by distance squared. The law applies to distances five or more times the maximum source dimension. For distances of only two or three feet, the illumination varies inversely as the distance.

Candle-power distribution curves guide the engineer in selecting lighting equipment. These curves are the graphic presentation of the distribution of light intensities of lamps or luminaires.

## Brightness

Brightness is produced three ways:

1. By self-luminous objects, such as the sun, a star, a lamp, directly to the eyes.

2. By light energy transmitted through objects, such as the sun through clouds, a lamp through a translucent luminaire (white glass globe).

3. By reflection, such as from the moon or sky, from the reflector in a luminaire, from most of the surfaces and objects we see daily.

"Foot-lambert", the term for brightness, equals the lumens per square foot emitted from a surface. The unit sphere, if perfectly transmitting, has its outer surface lighted to a brightness of one lumen per square foot, or one foot-lambert. Note that this is the projected area - not the actual area - of the sphere or other object considered.

Brightness is a concentration of candle-power, measured in foot-lamberts for sources of relatively low brightness as commonly used in illuminating engineering. A spherical globe with a one-foot radius containing a 1000-candle-power lamp and having an efficiency of 80% has a brightness of 800 foot-lamberts.

Brightness of specific light sources:

| | | |
|---|---|---|
| Candle flame | : | 1,500 foot-lamberts |
| 100w filament lamp | : | 50,000 " |
| 100w fluorescent lamp | : | 1,850 " |
| North sky | : | 1,000 " |
| Zenith sky | : | 300 " |
| Sun | : | 450,000,000 " |
| Moon | : | 1,500 " |
| Sirius - star | : | 4,275,000,000 " |

Measurements

In the laboratory, spectral energy - the wave-length analysis of visible energy - is obtainable by means of the spectrophotometer. Results are shown on a spectral distribution curve. Energy is visible only between 4000 and 7000 angstroms (violet to red). In the field, measurements are made by light meter - a light-sensitive cell which measures brightness and reflectance of surfaces.

With this scientific approach to illumination requirements, light is then controlled by the appropriate means, such as reflection, diffusion, transmission, absorption, refraction, polarization. Considerable study has been made to perfect reflector contours and other devices.

## ADDITION

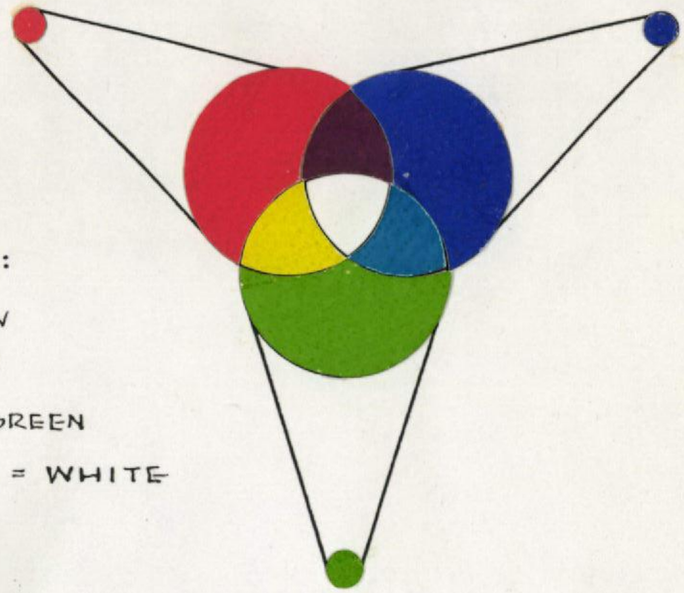
MIXING THE PRIMARY COLORS OF LIGHT — RED, GREEN, & BLUE:

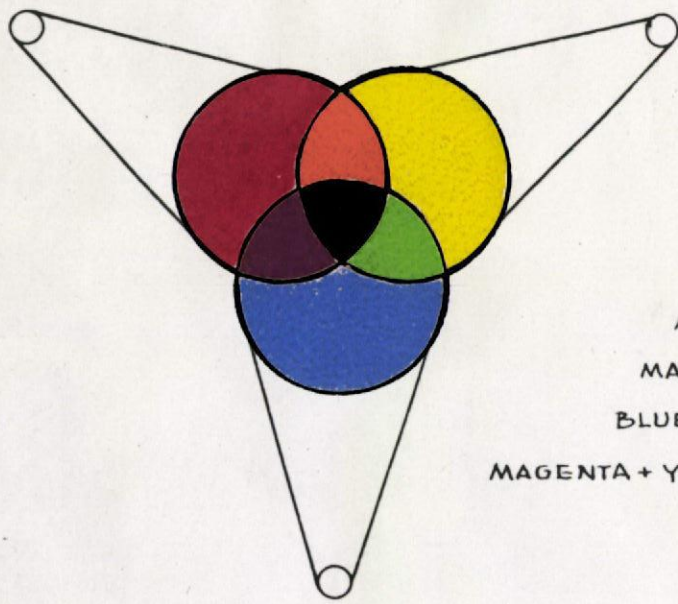
RED + GREEN = YELLOW

RED + BLUE = VIOLET

BLUE + GREEN = BLUE-GREEN

RED + BLUE + GREEN = WHITE





## SUBTRACTION

REDUCING WHITE LIGHT BY FILTERS — MAGENTA, YELLOW, & BLUE-GREEN:

MAGENTA + YELLOW = ORANGE

MAGENTA + BLUE-GREEN = VIOLET

BLUE-GREEN + YELLOW = GREEN

MAGENTA + YELLOW + BLUE-GREEN = BLACK

# LIGHT & COLOR

REFERENCE: FUNDAMENTALS OF LIGHT & LIGHTING
GENERAL ELECTRIC CO. BULLETIN LD-2

PLATE 12

## Light and Color

The color of an object is "the capacity of the object to modify the color of the light incident upon it" (General Electric definition).

The primary light colors are red, green, and blue. By addition of light colors, we see the following:

Red + blue gives violet.

Red + green gives yellow.

Blue + green gives blue-green.

Red + blue + green gives white.

By subtraction by using filters, we see the following:

Magenta + yellow gives orange.

Yellow + blue-green gives green.

Blue-green + magenta gives violet.

Magenta + yellow + blue-green gives black.

## I.C.I. Chromaticity Diagram

The International Commission on Illumination uses three terms to describe psychophysical color: dominant wave-length, brightness, and purity. (Equivalent to hue, value, and chroma of Munsell.) The I.C.I. tri-stimulus method uses a chromaticity diagram and specifies color in terms of mixtures of theoretical colored lights. Thus it is possible to coordinate all color systems. Furthermore, the specification of all possible colors may be shown on one chart. The I.C.I. system of coordinates makes possible the exact specification of colors mathematically by means of only two coordinates on a color map. The color coordinates of a light source are determined by spectrophotometer.

## Reflectance

A colored surface which looks halfway between black and white in lightness reflects only 20% of the light on it. Judging reflectance is therefore difficult. Value scales showing color samples with their reflectance for a number of illuminants have been developed through the cooperation of the Illuminating Engineering Society and the Inter-Society Color Council.

## Data and Application

Visually, a task and its environment must be considered together. The best light for seeing is yellowish, not green, not red, certainly not blue. This light plus the reflecting surface controls visibility. The brightness of the task surface should moderately exceed surrounding brightness. Average intensity on a task should be about 25 foot-candles. For critical tasks, 50 foot-candles is sufficient.

General room illumination should not exceed 100 foot-candles. Wall tones should be of low brightness both for visibility and for human appearance. The ratios of brightness for an area of considerable size should not exceed:

3 to 1 between task and immediate surroundings

10 to 1 between task and more remote surfaces

20 to 1 between luminaires or sky and adjacent surfaces

40 to 1 anywhere within environment of worker

In offices, an illumination level of 30 to 50 foot-candles is sufficient. In drafting rooms, 50 to 100 foot-candles is the range. Drafting rooms require large, diffuse luminaires.

## Fluorescent Lamps

Tests with fluorescent lamps have shown that matching of lamp color to filament or to average da light does not establish optimum spectral distribution for the color appearance of materials. Further research was necessary. Public opinion was tested on various combinations of light and materials. For example, it was found that blond hair is enhanced under a warm tint of light, while titian hair is enhanced under filament light. In general, for one color viewed at a time, the public choice is a lamp which enhances saturation and brightness with a minimum shift in the hue of the sample receiving the light. (General Electric research.)

For social environments, including some shops, a warm source is required containing red and yellow for favorable rendition of complexions, foods, and usual floor and wall coverings. Filament light is suitable for these. The general preference for soft white and filament lamps is due to their spectral compatability with warm environment materials.

Fluorescent light is definitely unfavorable to some foods, e.g., scrambled eggs, cherry and grape jelly.

## Colorants and Color

For working environments, the lighting engineer suggests surface colors on the basis of reflection factors. Most experts list four groups of colors, all recognizing the one group called "relaxing" or "tranquilising". This neutral group provides a satisfactory background level for lighting engineers. The Holophane Company has developed charts based on colors which neither excite nor disturb, are thus applicable in working environments. Final consideration must always depend on the combination of colorants and light sources.

## Color Matching and Differentiating

Matched colors must be checked by at least two light sources to be certain of accuracy.

In color-grading operations, deluxe cool white fluorescent is best, since it contains equal amounts of all colors.

For textiles, small color differences in blue, purple, violet, and orchid are best detected under tungsten-filament light, which is rich in red and yellow energy. Differences in pink, red, orange, and yellow are best seen in light rich in blue and green, as natural daylight, daylight fluorescent lamps, and standard cool white. There is little choice in illuminants for green and yellow textiles.

## Fading

Wave-lengths producing fading may be different for every colored material. Natural and artificial light sources vary in their fading potentialities because of variations in spectral distribution of the energy radiated.

The fading of textiles by daylight is principally due to radiant energy in the visible spectrum. Any filter which reduces fading must greatly reduce the energy in the violet, blue, green, and yellow parts of the spectrum, hence greatly alters the colored appearance of the objects illuminated through it.

### Generalizations on Fading

1. Change in the amount of foot-candles or time is not important as long as the product of the two remains same.

2. Oxygen is necessary for fading; therefore, put the specimen in an evacuated enclosure.

3. Humidity does not affect the rate of fading but may affect the texture of the material.

4. Temperature has little influence until it reaches 150F, when fading doubles over 85F.

5. Fading is produced by radiation. Filtering out ultra-violet light does not appreciably reduce fading.

6. Illuminants vary in fading power. North sky fades more than the summer sunlight; both fade more than fluorescent or tungsten-filament lamps.

7. Fastness of dye is important.

In meat displays, fluorescent lamps are placed inside the case because of low heat, while tungsten-filament lamps are placed outside the case because of high heat. The only meats affected in color by light are the processed meats such as bologna, meatloaf, boiled ham.

## Printing

In printing, the basic inks are red, yellow, blue, black. Four plates are required, one for each color. The four plates are half-tones, which are really closely spaced dots or other textures. By overprinting, colors appear to fuse, so that color is mixed in the eye. There is seemingly no limit to the number of colors thus obtainable. Great paintings are reproduced in faithful color with only four colors of ink.

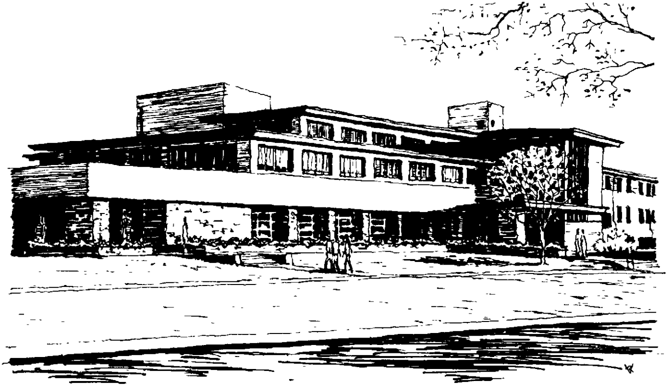
Printing proofs must be examined frequently. Blue, red, and especially yellow are difficult to scrutinize, so colored lights are used to facilitate legibility. For example, saturated blue light makes yellow ink look black. Yellow ink reflects no blue; the light source is blue; therefore yellow ink reflects no light.

The importance of a basic knowledge of illumination to the architect can hardly be over-estimated. The illuminating engineer is another member of the sizeable team required to produce good architecture.

# PART III

## A N   E X P E R I M E N T

PLATE 13



THE MEMORIAL STUDENT CENTER

A. & M. COLLEGE OF TEXAS NORTH APPROACH

Sample of Questionnaire used in this experiment:

GIVE ME YOUR OPINION ON THE COLOR OF THE M. S. C. !

WHY? This is a poll of public opinion on color, statistics to be used in my thesis on "Color in Architecture". Your name will not be used.

1. Observe the EXTERIOR of the M.S.C. from the common north approach. Note the limestone, brick, facia (edge of roof), etc. Check your opinion below.

2. Observe the SNACK BAR as you sit there. Note ceiling, walls, floor, furnishings, etc. Check opinion below.

3. Observe the BALLROOM on the second floor. Note ceiling, walls, floor, furnishings. Check opinion below.

| Your Opinion | North Exterior | Snack Bar | Ball-room |
|---|---|---|---|
| The color combination is very pleasing. | | | |
| The color combination is annoying. | | | |
| The color combination is neutral: neither very pleasing nor annoying. | | | |
| If the color combination is not very pleasing, how would you change the colors? Comment at right: | | | |

Have you had any special color training other than in routine school courses required of all students?

No_________Yes_________Comment__________________________

This experiment was a comparison of my opinion with public opinion on the colors of a contemporary building. The building is the Memorial Student Center (completed 1950), A. & M. College of Texas.

The procedure was to record my opinion, then to check public opinion by distribution of mimeographed forms to be filled out. These forms were returned to me either at the Memorial Student Center (M.S.C.) or through the campus mail. My opinion is recorded below. A copy of the forms distributed is appended. Results are followed by my conclusions.

The parts of the M.S.C. observed were the exterior from the common north approach, the Snack Bar (or Fountain Room), and the Ballroom.

## My Opinion

### North Exterior

To me, the color combination of the North Exterior is neither very pleasing nor very annoying. There is a slight clash between the dull red of the facia and the orange tint of the brick. Assuming the brick satisfactory, I would change the facia to a hue containing more darkish brown and less of the present red. Assuming the facia satisfactory, I would use a range of brick tints nearer to cream and light gray than to the present orangish tone. Otherwise, the colors of the exterior are very pleasing from the common north approach. (This does not include the hotel wing, whose brick colors are ugly.)

Snack Bar

To me, the colors of the Snack Bar, or Fountain Room, are very pleasing, with the exception of the yellow mullions between the pivoting glass panels which separate the room from the corridor. I like the red face-brick here. I like the green ceiling, whose beams reflect an interesting range of tones from yellow-green to blue because of a variety of concealed lamps. The floor color and the furniture color seem to harmonize with the rest of the room. But those strong yellow mullions fight with almost all the other colors. Indeed, gazing at the yellow mullions spoils the whole color scheme. To enjoy the Snack Bar, I simply look away from the yellow mullions, which could be harmonious if painted a very pale yellow, almost white.

Ballroom

To me, the Ballroom is annoying with its strong red and blue. The red brick flanking the stage is too strong and too dark for easy audience concentration on the stage. The blue of the reinforced concrete arches is too strong and too dark next to the white ceiling panels. The intense blue drapes further increase the vibratory effect between the red and the blue. Now, this effect may be satisfactory for a ball, but I think it is too strong for audience events. The whole room appears to be specially decorated for the 4th of July. I would change the color of the arches to a much lighter, very grayed blue - more gray than blue. Other than that, I would use either a different tone or a different and lighter-colored material for the brick panels flanking the stage. The whole color combination needs re-study.

## Public Opinion

It is readily acknowledged that this experiment means little when discussed only in writing. It should be discussed while viewing the areas in question. Fortunately, most persons who read this will have viewed those areas. So on with the comparison.

### North Exterior

Refer to the questionnaire distributed to the public.

Of the 106 forms returned, votes on the North Exterior totaled as follows:

"The color combination is very pleasing"...........100

"The color combination is annoying"................ 1

"The color combination is neutral"................. 5

Of the 100 who voted "very pleasing", 89 checked that they had had "no special color training", while eleven checked "yes", that they had had some special color training. The six who checked other than "very pleasing" all checked "no special color training".

### Comments by the Public

The one person who checked "annoying" commented, "Use of materials for color contrasts annoying."

One person who checked "neutral" commented, "Brick is a little too 'pale'. Looks dirty."

No comment was offered by anyone who checked "yes" on the question of special color training.

## My Interpretation of Results

Obviously, there was overwhelming enthusiasm for the color of the North Exterior. But conclusions should not neglect these considerations: the forms were handed out inside the building to people enroute to the Snack Bar. Most of the forms were returned by these people as they left the Snack Bar. Therefore, their opinion was based on memory. The memory of the exterior appearance is, of course, very pleasing. As two persons commented in writing when they checked "very pleasing" for everything: "Damn good for a place like this." Memory, then, gives the M.S.C. highest rating compared to every other building on the campus. I submit that this memory is of the M.S.C. as a whole, including effects other than color. Even if all of these people had gone out to study the exterior before checking the questionnaire, they might not have changed their minds. The theoretical average man has some sense of color but no finely discriminating sense.

Perhaps the two written comments unfavorable to the North Exterior support my criticism, though not explicitly. Recall that my criticism noted a "slight clash". As I warned, any evaluation of comparative judgments would be personal. I hold to my original criticism.

Snack Bar

Of the 106 questionnaires returned, votes on the Snack Bar (Fountain Room) totaled as follows:

"The color combination is very pleasing"........... 86

"The color combination is annoying"................ 6

"The color combination is neutral"................. 14

Of the 86 who voted "very pleasing", 77 checked that they had had no "special color training", while nine checked "yes" on the question of special color training. None of the six who voted "annoying" had had any special color training. Of the 14 who voted neutral, eleven checked "no", three checked "yes" on special color training.

Comments by the Public

Of those who checked "annoying", comments were these:

One would change the Snack Bar to "pleasant shades of green".

Another wrote: "Do not care for greens in eating places, unless are (sic) very soft almost neutral."

A third wrote simply, "Too many don't blend."

Of those who checked "neutral", comments were these:

One would "change to light blue".

Another considered the "color ok except....variation of strong linear patterns creates cluttered appearance (bricks, roofbeams, booths, etc.). Also floor color not suitable for Snack Bar, looks dirty all the time."

A third wrote, "Never gave this room much thought. Not striking."

Another comment: "I think the colors are fine. An eating place is more restful with colors which do not glare out."

Only one comment was written by a person who checked "yes" on special color training; that was a comment favorable to all areas considered: "I think they have used very good taste in all their color selections."

## My Interpretation of Results

No one mentioned the one color - the strong yellow of the mullions - to which I objected, so I do not know to what extent this color influenced opinion.

The objection to "variation of strong linear patterns" is more a criticism of form than of color. The comment by the same person, "Looks dirty all the time," indicates that such a psychological factor could influence one's entire impression of the place, including its color. I don't agree with the criticism of the floor color, for in its grayness it remains neutral, and in its speckled texture it performs the function of making dirt less obvious.

The objection to glare is justified if it is a criticism of the natural light control. Glare through the windows is adversely reflected from some surfaces.

The percentage of opposition to the Snack Bar surprised me, not that it was large, but because it slightly exceeded opposition to the Ballroom. If I knew that the mullions were the deciding factor, I'd no longer express surprise, but no mention was made of the yellow. Perhaps there would have been even more criticism of the Ballroom if the participants had studied it as they did the Snack Bar.

Ballroom

The 106 forms returned produced the following totals on the Ballroom:

"The color combination is very pleasing"............ 86

"The color combination is annoying"................ 5

"The color combination is neutral"................. 12

No opinion recorded................................ 3

Of the 86 who voted "very pleasing", 78 checked "no", eight checked "yes" on special color training. Of the five who voted "annoying", four checked "no", one checked "yes" on special color training. Of the twelve who voted "neutral", the totals on special color training were eight "no", four "yes".

Comments by the Public

Of those who checked "annoying", comments were these:

According to a former student of Texas State College for Women, the Ballroom is "too dark". She wrote, "If curtains are drawn back, there is a glare in the Ballroom in daytime. It is bad during luncheons."

Another person would change the colors to "shades which do not clash ....as the blue and rose shades used".

Of those who voted neutral, comments were these:

One wrote, "Color used on beams is rather dark."

Another commented, "Would rather see old rose and browns in the Ballroom."

Of those who voted "pleasing," other than the two who gave the general comment for everything, "Damn good for a place like this," only one offered a comment referring to the Ballroom alone: "I like this very much."

Of those who offered comments, only two were by persons who checked "yes" on special color training. One of these was the above comment including the phrases "too dark" and "glare". The other comment: "I think they have used very good taste in all their color selections." Both of these conflicting comments were by ladies.

My Interpretation of Results

Again, even more than in the case of the exterior, a large number of persons apparently judged the Ballroom from memory rather than by going upstairs to study it. I give credit to the three persons who admitted they hadn't studied the Ballroom by simply leaving that part of the questionnaire blank. Opinion on the Ballroom statistically compares very closely to opinion on the Snack Bar. Once more, the room is quite pleasing to a large majority, but the adverse criticism compares somewhat with mine.

The comment on strong contrasts was well studied: room "too dark", then too much glare with drapes open.

The comments on the "clash" of shades and on the darkness of the arches support my contentions.

For students, the appeal of the Ballroom may well be strong because of association with an enjoyable dance held there. For the person who attended a luncheon there, the glare was too much. This supports my contention that the room was not so well decorated for affairs other than dances.

## Conclusions

My personal conclusions begin with the statement that people in general are satisfied with color combinations which are not bad. Nevertheless, the architect must design for the person with the acute color sense, for this may be the person with sense enough to hire an architect.

In the case of the Memorial Student Center, the pleasant atmosphere and design features of the entire building so far exceed those of any other building on the campus that the reaction to any aspect of the building is enthusiasm.

Of those who took the trouble to analyze the areas in question, the comments prove only that public opinion differs from person to person.

My ego, I suppose, prompts me to maintain that I have a good color sense. This contention is fairly supported by the fact that I have studied color to this extent. However, the final proof of my color sense as applied to architecture may be determined only by the degree of public acceptance of my work. I hope, at least, that I am developing a good color sense. It is possible that my students will teach me more than I teach them.

# PART IV

# HOW SHOULD COLOR BE TAUGHT IN ARCHITECTURE?

How should color be taught to the student of architecture?

## Introduction

The introduction to color should include some history plus the basic physics, physiology, and psychology pertaining to color. The explanation should be kept very simple and brief at first, for the objective is not to confuse but to dispel any preconceived misconstructions on the subject in the minds of young students of architectural design.

When the basic relationship of light, the eye, and the mind has been established, there should follow an explanation of the two types of complements, psychological and pigmentary. It is too early for explanation of harmonies. Indeed, individual experimenting to discover harmony might well precede explanation of what is known about harmony.

## Color Wheels

The first formal exercise is usually the execution of a color wheel illustrating pigmentary complements. Neutral gray is placed at the center of the wheel. Each pair of complements is determined by their capacity to produce approximately this neutral gray when mixed together. With red, yellow, and blue as the basic triad, a full hue circle is developed around the gray center. Tones of half-hue and half-gray are then mixed to form the spokes of the wheel.

It might be wise to execute a second color circle to illustrate psychological complements, which are determined by after-image. A comparison of the two circles could then be made. It should be clearly understood that the pigmentary wheel is for studying pigment mixtures, while the psychological circle is for designing with color.

These exercises are done with inexpensive but satisfactory paint: "showcard" or "tempera", a water-based paint which - in its better brands - gives the flat, even surfaces necessary.

## Color Plus White and Black

The second exercise is a study of the combination of a hue with white (tints), with black (shades), and with white and black (tones). A triangular hue plane illustrating the gamut is a tried and satisfactory exercise.

## Basic Harmonies

After some free experimenting in which the student represents his own ideas of color harmony, study of harmony is made through a series of color plates. At first, it may be wise to give the student ready-made designs so that he will concentrate on color rather than form, but this is debatable. Soon color and form must be studied together, beginning with abstract designs. The sequence in color harmony study might be as follows:

1. Monochrome: a simple, abstract composition involving only one hue and its various combinations with white and black and grays.

2. Complements: an abstract study with two colors which are psychologically opposite. White and black may be used as modifiers. Contrast in values, which promoted itself in the monochrome, must be carefully studied from here on.

3. Triad: a composition using three hues which form an equilateral triangle on the color circle. Again, white and black may be added. At this point, debate is likely to arise concerning the psychological and pigmentary triads. Some explanation of systems of color notation such as Ostwald and Munsell might be inserted here. Perhaps the only fact retained by the student at this point will be that the triad relationship is somewhat flexible. More important than the pinpointing of the triad hues is the study of values, forms, and areas in the composition.

4. An abstract study with analagous colors is next in order, e.g., yellow-orange, orange, and red-orange. Once more, value is important.

5. Finally, the split may be studied: a hue plus two colors equally spaced each side of the hue complement. The connected trio on the color circle would form an isosceles triangle.

## Color and Texture

Now comes the relationship of color to actual materials, which means relating color to texture. The only approach is to observe actual materials by bringing into the laboratory samples of wood, tree-leaves, pieces of fabric, bricks, metallic objects, etc. Study texture and color by eye. Place the samples together in abstract composition. Then try imitating texture and color with paint.

Stretch paper or water-color paper is the most satisfactory background for developing texture along with color.

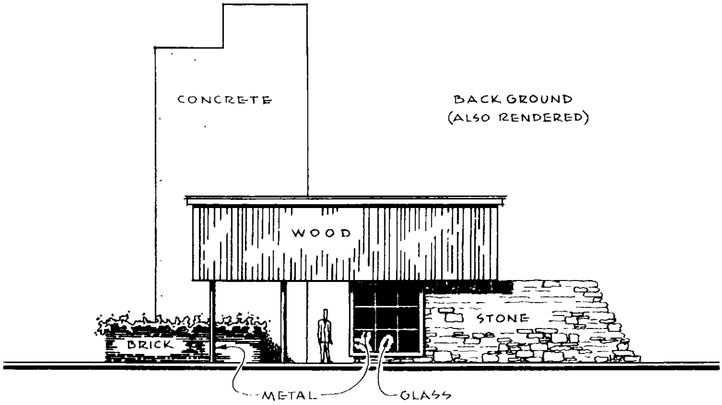
The first experiments might show the texture and color of materials at full scale. Then materials should be viewed at a distance to observe their effect at a much smaller scale. Building materials are, of course, most important.

The first formal exercise should be a monochrome in gray, white, and black, for the purpose of establishing value as well as texture. Various textures are not difficult to learn, but value seems to be difficult to impress on the young architectural student, especially when he uses color. Let him learn value first - how to contrast areas for legibility - through monochrome.

This exercise might be in simple elevation, showing a group of building forms with wall materials specified. The materials of prime importance are concrete, wood, metal, brick, stone, glass. Plant forms may be included for variety in color and texture, but a detailed discussion of landscaping is premature.

Having studied texture and value, the next step is to repeat the rendering in full color. The combination of colors is the new problem. Now the importance of studying value first may be seen, for the student - without an appreciation of value relationship - will inevitably use colors which contrast in hue but are so monotonous in value that they vibrate. This is a difficult exercise, often requiring re-working of rendered surfaces.

PLATE 14




# MATERIALS RENDERING EXERCISE

STUDENT EXERCISE FOR STUDYING TEXTURE, VALUE, & COLOR COMBINATIONS. RENDERED FIRST IN MONOCHROME (GRAYS), THEN REPEATED IN FULL COLOR.

A value check on the color rendering may be made by photographing it in black and white.

## Color in Actual Buildings

Aside from rendering building materials in color, the student should go on conducted tours to observe the solutions of practicing architects. Some of these solutions should be noted as lessons on what not to do. However, in the case of firms which aim for the best in design, an expert on color (usually a member of the firm) sees to it that color is an integral part of the design, not a last-minute addition.

## Watercolor Sketching

As a relief from the exacting task of rendering building materials as they actually appear, it is a good idea to arrange for frequent watercolor sketching sessions - out-of-doors whenever the weather allows. In such sketching sessions, the student should be guided very little, rather encouraged to experiment with color and form - to express his own impression in whatever manner is natural, whether precise or primitive.

## Rendering in Color

Rendering of architectural solutions in color for the sake of studying the medium and its coloration possibilities is good practice. An attempt may be made to present a building as it might actually appear, but this is extremely difficult, even for the student with the most acute color sense. The usual media are tempera, water-color, pastels, and colored pencils. Each medium should be studied for its own behavior, with an eye to good color composition.

While it is good practice to study color through architectural renderings, it should be realized that a rendering cannot show the final appearance of the building. Therefore, color should not influence a jury as to the merit of an architectural solution when presented as a drawing or model. Unfortunately, color often does influence a jury, for good color is likely to bring a commendation (of the color), and bad color is bound to bring a condemnation. Perhaps this is the solution: present all student designs in black and white, judge them on solution and form. Then, execute them in color as a separate exercise.

## Other Experiments

Further study of color may be made by executing collages (pasting various materials to a sheet in interesting composition), by building models - both architectural and abstract, by experimenting with photography, by experimenting with light sources and their effects. Experiments originated by the students often prove most interesting.

## Time

In learning color, the element of time must be considered. The student should be encouraged to record his opinions on color, then re-examine a composition or building months or years later to observe his own development in color analysis. This is especially advisable for the student who has a poor color sense but insists his judgment is correct. (However, who is to offer final proof that his color sense is poor?)

The student should consider time, too, as it relates to architectural practice. He should begin to learn something of the behavior of the colors of building materials subjected to the test of time.

## Selling Architecture

It is always a good idea for the student to dig into references for professional advice on color, but this is not enough. This student is supposedly a future practicing architect, practicing to please his clients. This does not mean producing such monstrosities as the client may insist on, but rather pleasing the client by doing a first-class selling job on what is good architecture. In the case of color, the student will do well to poll and note public opinion. A good color sense can best be developed by listening to as many opinions as possible, both amateur and professional, then drawing one's own conclusions.

If the color of your architecture pleases the owner now, half the battle is won. But the other half is not won till next year when the owner declares once more that he is proud of the color.

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